APPLIED MECHANICS Reviews

A CRITICAL REVIEW OF THE WORLD LITERATURE IN APPLIED MECHANICS AND RELATED ENGINEERING SCIENCE

REVS. 3398-3950 VOL. 14, NO. 7 JULY 1961

APPLIED MECHANICS Reviews

Published Monthly by THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS at Easton, Pa., and edited by Southwest Research Institute with the co-operation of Linda Hall Library.

APPLIED MECHANICS REVIEWS, July, 1961, Vol. 14, No. 7. Published Monthly by The American Society of Mechanical Engineers at 20th and Northampton Streets, Easton, Pa., U. S. A. The editorial office is located at the Southwest Research Institute, San Antonio 6, Texas, U. S. A. Headquarters of ASME, 29 West 39th St., New York 18, N. Y., U. S. A. Price $2.50 per copy, $25.00 a year. Changes of address must be received at Society headquarters seven weeks before they are to be effective on the mailing list. Please send old as well as new address. . . . By-laws: The Society shall not be responsible for statements or opinions advanced in papers or printed in its publications (B13, Par. 4). . . . Entered as second-class matter, January 11, 1948, at the Post Office at Easton, Pa., under the Act of March 3, 1897.

HOW TO OBTAIN COPIES OF ARTICLES INDEXED: See section after Books Received for Review.

Editorial Office: **APPLIED MECHANICS REVIEWS, Southwest Research Institute, 8500 Culebra Road, San Antonio 6, Texas, U. S. A.**
Subscription and Production Office: **The American Society of Mechanical Engineers, 29 West 39th St., New York 18, N. Y., U. S. A.**
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APPLIED MECHANICS REVIEWS

VOL. 14, NO. 7 JULY 1961

NEW PATHWAYS IN THE AERONAUTICAL SCIENCES

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MASSACHUSETTS INSTITUTE OF TECHNOLOGY

THE PAST

It is usual to think of the technology of heavier-than-air flight vehicles as beginning with an invention of the Wright Brothers. The first flying machine could scarcely be called a random invention standing alone in its time even though it contained many ingeneous contributions by its talented inventors. It was another in a stream of machines which appeared following the start of the Industrial Revolution in the latter part of the 18th century. Scientific progress, profit motives and a tendency of natural philosophers to turn their talents from philosophical speculation to machines combined to produce this stream. Natural philosophers discovered that the scientific methods of observation, induction, deduction and experiment were applicable not only to the original subject matter of basic science but also to the conception and development of machines. Scientific progress derived from searches for pure knowledge, undertaken in earlier centuries, prepared the soil. Then the fallow land was triggered into production. The invention of each new machine was based to some degree on earlier discoveries of basic science, but once invented, it became the key to new fields of scientific research and industrial development. The history of science and technology documents many examples of such creative spirals. Faraday's experiments led to the invention of the generator which motivated the discovery of new physical principles and the founding of an electrical industry. Maxwell's mathematical studies of electromagnetic wave theory led to telegraphy and telephony which in turn posed new problems to physicists. The electric telegraph is an example of an invention resting upon an earlier purely scientific research. In return, the mirror galvanometer, invented in connection with submarine telegraphy, benefitted pure science immensely.

The triggering of the machine era was due largely to James Watt who brought the steam engine to a serviceable form nearly a century and a half before the flying machine. There are strong similarities in the early development of the steam engine and flying machine. Both machines were in a crude state of being when the inventors arrived on the scene: the Newcomen engine in the case of Watt and the Langley machine in the case of the Wrights. Both were developed by skilled mechanics with the advice of scientists. Watt received counsel from Professors Joseph Black and John Robison of Glasgow. The Wright Brothers benefitted from written communications from Octave Chanute, Samuel Langley, and others with formal scientific training. Both machines were developed with small sums of money, furnished from the inventors' savings. Both machines rested upon vaguely defined physical principles formulated previously by natural philosophers who had no particular interest in such machines. What is more important, both machines motivated the later discovery of a vast number of new physical principles. A few early scientists seemed willing to divide their energies between the pure and the applied. Some, stimulated perhaps by the profit motive, or others by a desire to benefit mankind directly, turned their attention to machines. Thus, the engineer was born. The steam engine was perhaps the earliest object of a high degree of such attention. The efforts of Carnot, Kelvin and others to understand and improve efficiencies resulted in the discovery of the second law of thermodynamics. This early broadening of thermodynamic theory led to new heat machines, which in turn motivated the discovery of new insights into the processes of nature. Those who engage in aeronautical research are participants in a similar creative spiral polarized around flight vehicles.

CASE STUDIES.

Flight vehicle technology has for many years been divided roughly into the four branches called aerodynamics, structures, propulsion and control and guidance. The breakdown is old, but it is still good. The flight vehicle, to be sure, may range over a wide spectrum of machines from helicopter to space vehicle. However, all such machines may be said to have these four elements in common. High aerodynamic efficiency in terms of optimum lift-to-drag ratios, high structural efficiency measured by high strength-to-weight ratios and high propulsive efficiency characterized by high thrust-to-weight ratios are goals sought in virtually all flight vehicles. Control and guidance by automatic devices becomes a common requirement as performance is raised.

Case studies of the branches of flight technology can point up the contributions of basic science to the airplane and the feedback contributions of the airplane to basic science. Two such studies are illustrated graphically in Figs. 1 and 2. In Fig. 1, the fragment of aerodynamics called supersonic aerodynamics is used to illustrate the extent to which the airplane has motivated fundamental contributions. In this chart the number of significant contributions to the fundamentals of supersonic aerodynamics have been superimposed over the year of their appearance. Whether a given contribution is, in fact, significant is a matter of opinion, and such a chart would vary somewhat in detail depending upon its author. However, its over-all appearance should not vary significantly with different authors. Only work prior to 1950 has been included since more recent work is particularly difficult to judge. There are several interesting features

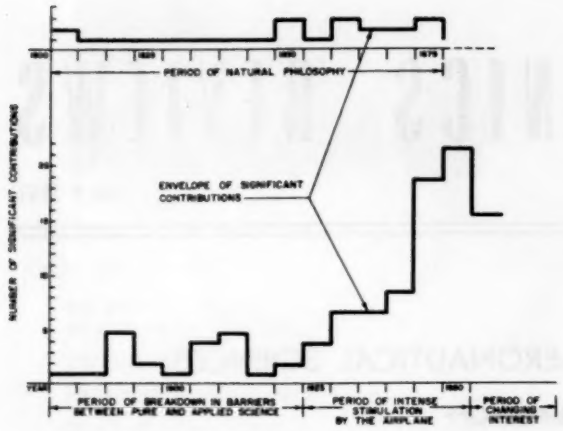

Fig. 1. Evolution of Theory of Supersonic Aerodynamics.

about Figure 1. The underlying principles of supersonic aerodynamics certainly began with Newton nearly three centuries before man succeeded in flying supersonic himself. d'Alembert, Laplace and Lagrange all contributed underlying bits and pieces prior to the beginning of the nineteenth century. In 1808 the French mathematician Poisson integrated Navier's equations of equilibrium of an elastic solid and showed that wave motion results if a disturbance is produced in a portion of the body. The English physicist, Stokes, while carrying Poisson's work forward, proposed the concept of a shock wave in 1848: "that a surface of discontinuity is formed across which there is an abrupt change in velocity and density." Throughout the 19th century, the subject received increasing attention. Earnshaw of England and Riemann of Germany, working independently in the 1860's, contributed significantly. Rankine and Hugoniot in the latter part of the 19th century finally placed the subject on a firm theoretical basis. This was virtually the end of the era of attention by pure natural philosophers. As the barriers between applied and pure science were broken down, widespread practical interest arose in nonlinear wave motion. Applications were discovered in explosions and projectiles, and in about 1920 the airplane began to exert some influence on the direction and rate of research. This influence grew until about 1950, the time when practical manned supersonic flight was realized. There is some evidence to indicate that after 1950 there occurred a period of changing interest in which the more imaginative workers in fluid mechanics turned their attention to other fields such as magnetohydrodynamics.

Figure 2 shows a similar figure which illustrates how the airplane stimulated fundamental contributions to a fragment of

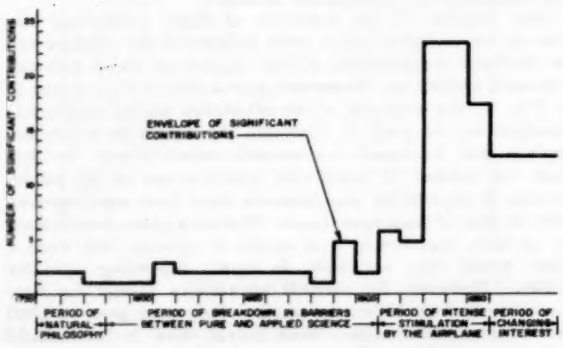

Fig. 2. Evolution of Buckling Theory of Thin Shells.

the technology of solid mechanics: the area of buckling of thin shells. In the general area of solid mechanics, the breakdown of barriers between pure and applied science occurred at a relatively early time. Scientific workers in solid mechanics seem to have been greatly influenced by the steam engine and by bridges, buildings and military fortifications in the 18th century. Figure 2 shows that the period of most intense research in thin shell buckling occurred about 1930. We know that this is the period of change over in the airplane from internal trusses to monocoque shells. It seems clear that there has been a period of slowly waning interest in this field after 1940.

NEW PATHWAYS AND THE BROADENING SCIENTIFIC BASE.

At the time that the title aeronautical engineer was coined, each of the four branches of flight technology had a parochial flavor. They rested upon one or at most a couple of the basic sciences. That this is no longer the case is evident to all who work at the frontiers of flight technology.

The increase with time of the underlying sciences required for a complete understanding of modern aerodynamics provides one of the best examples. At the beginning, the aerodynamicist based his predictions on the theories of classical hydrodynamics in which the air was assumed incompressible. The state properties of the air were not involved and a relatively simple theory embracing equilibrium and kinematics was all that was required. Approach to the transonic region meant that thermodynamics was needed. At first a simple thermodynamic model of the air could be employed in which it was unnecessary to inquire of the internal behavior of individual molecules. Later at Mach numbers of about 5 to 10 the internal vibrational degrees of freedom of the air molecules behind the shock wave became excited and dissociation and recombination commenced. This called for chemistry. Then, at Mach numbers of about 12 to 15 ionization was seen to produce enough free electrons to have a significant effect on the physical properties of the shocked air. Thus, the floodgates were opened for modern physics and electromagnetic theory to come onto an already crowded stage. There is no limit to the research pathways in fluid mechanics which have been opened by very-high-speed vehicles carrying ionized boundary layers. Fundamental to all of this research are adequate physical models for the chemical kinetics of gases.

But aerodynamics does not require research involving chemistry and modern physics in order to benefit flight vehicles. If we take the two vehicles most likely to affect the life of the average citizen within the next decade, namely the helicopter and the supersonic transport, we can select aerodynamic research problems of great interest. For example, if the question of understanding rigorously and in detail the aerodynamics of rotors in forward flight could be settled, it would prove of tremendous value in the improvement of helicopter efficiency. In the supersonic transport, a deeper insight into the aerodynamic behavior of low-aspect-ratio wings is needed in order to bring an optimum compromise between the aerodynamics of flow in the $M = 3.5$ range with that of the low-speed separated-flow regime where leading edge attached vortex flows are present.

In a scientific sense, the discipline of structures was characterized for many years by the fitting of an endless variety of boundary conditions to the well-established principles of elasticity. This is not to say that the tailoring of the principles to fit the applications did not require great skill, but the underlying science tended to remain for a very long period of time at the same level as incompressible potential flow aerodynamics. Then, like aerodynamics, the microscopic behavior of the material of which the structure was made commenced to interact more closely with its over-all performance. This interaction has traditionally been accounted

for by phenomenological models such as those of plasticity, creep and viscoelasticity. Such models are employed to construct state equations which supplement the usual equations of solid mechanics of equilibrium and compatibility. The presence of such factors as shear stress, material memory and phase change make models of this kind exceptionally difficult to construct. There is as yet no universal phenomenological model which holds over the temperature-stress-time limits of interest for a given material. On the one extreme, we have the familiar low-stress elastic behavior with its possible complexities of anisotropy. On the other extreme there is the very high stress and temperature environment where the material behaves essentially as a compressible fluid. The latter environments may be associated, for example, with hypervelocity impacts above 10 km/sec. Here we may also disregard rate-effects, nonequilibrium states, shear stresses and property changes depending on deformation history. Equations of state of solids under these conditions have become available from the work of the Los Alamos groups and others for pressures up to several megabars, and from the Fermi-Thomas-Dirac theory for even higher pressures. The important intermediate range between these extremes is in much less satisfactory shape. It is clear that the search for satisfactory models of material behavior opens a vast area for research. If left entirely to metallurgists and solid-state physicists, this search would never be completed. It must be participated in by individuals knowledgeable in solid mechanics who make it their business to work at the boundary between solid mechanics and the solid state.

The chemistry of surfaces will also become an important factor in structures operating in space. Experiments on the fatigue and creep properties of materials down to ambient pressures of the order of 10^{-4} mm of Hg have indicated that the rate of crack propagation is significantly influenced by its environment. Mechanisms of these phenomena are not fully understood. It is enough to note here that whatever these mechanisms turn out to be they will involve a mixture of solid mechanics and chemistry.

Like aerodynamics, not all of the important aeronautical research problems of structures involve chemistry and solid-state physics. Research on the instability behavior of pressure-stabilized membranes such as toroids, hyperboloids and other odd shapes in the presence of orthotropy is needed. Much may also be learned about the detailed behavior of composite materials without going beyond the traditional bounds of elasticity and plasticity. Simple viscoelastic models are also finding new employment in such diverse fields as the structural behavior of propellant grains.

The underlying scientific disciplines which must be brought to bear for meaningful research in propulsion and control and guidance are no less restricted in breadth than those of aerodynamics and structures. In propulsion, the scientific base is broadened by the need for research in combustion and in techniques for using electrical energy to expel mass and produce thrust. In control and guidance, the research required to produce reliable inertial gyro units with drift rates of the order of one minute of arc per hour has extended into every possible corner of the basic sciences. The difficulty of this task was emphasized by C. S. Draper when he pointed out that such a drift rate requires a center of mass deviation of the gyro of less than some fifteen crystal lattice dimensions of the materials employed for gyro construction.

A continuous broadening of the scientific base is not new to aeronautical scientists, but a degree has been reached where the difficulties of doing research in a given branch of flight technology are immense. It is at once a source of weakness and of strength. It is a source of weakness because it discourages practitioners who have a parochial interest in one of the basic sciences, or practitioners who shudder at the thought of mastering so many of them. It is a source of strength because it will encourage a new kind of university education in applied science. One of the most important ingredients in the applications of science at all levels is that of conceptual models of nature which are used for mathematical or physical reasoning. The different divisions of science are old and traditional but they are nevertheless arbitrary. They may be classified by their conceptual models. A metal beam to an engineer is a mass of homogeneous elastic isotropic material subjected to certain force and displacement boundary conditions; to the chemist a collection of complex molecules; to the metallurgist a collection of randomly oriented grains and crystals; and to the solid-state physicist a swarm of nuclei and electrons or wave groups. We can construct a model of the physical world and trace the relations between its parts, but we cannot by such models represent the intrinsic reality of nature. By applying the tools of reasoning to models we can infer that something exists in addition to our initial thoughts about them. If the model is consistent with experimental observation, it is regarded as a valid model. Pure scientists are engrossed in improving nature's models and applied scientists apply them to machines. This is where the applied scientist is challenged by modern research in flight technology. He must know about and be interested in more than one model; in fact he must know about several of them if he is to be effective.

The discipline of mathematics is a tool which underlies all branches of flight technology. M. J. Lighthill's description of the role of mathematics in aeronautics as a generator of new physical ideas and as a means of calculating answers is succinct and descriptive. Mathematics as a generator of new physical ideas is a familiar role, and perhaps its most important. Such phenomena as aeroelastic instabilities and new magnetohydrodynamic wave phenomena are examples where mathematical deduction preceded accurate physical description. The modern computing machine has increased many fold the capacity of mathematics as a means of calculating answers. However, since such machines cannot think and can only follow instructions they have many well-recognized limitations.

THE RESEARCH WORKER AND HIS ENVIRONMENT

Research workers in the applied sciences are distinguished by their differences. Some have been creative, some meticulous, some versatile, some narrow, others routinely industrious—all types being necessary for progress. Isaac Newton, representing the dean of the natural philosophers, combined at once a capacity for incisive inductive reasoning, cleverness with his hands, and holding a bureaucratic post as Director of the Royal Mint. Like most of his contemporaries, he worked virtually alone. The industrial revolution tended to push scientists into activities other than those which proceeded from their own imaginative thinking. Prandtl was a prototype of an important era. As a young engineer entrusted with the important work of developing engineering mechanics at Gottingen, he proved that research and teaching of applied science could be in full harmony with, and could in fact enhance, the high ideals of university education. He established a chart and compass for the first class engineering graduate school. But the era typified by Prandtl and his students is also passing. The aeronautical sciences have become highly organized. Either the government or industry or both are involved in some way in almost every undertaking. The number and size of research teams is increasing. Their results are awaited daily by the military and the producers of machines. The result is an era of flight vehicle development in which scientific methods applied by large teams have compressed into a few years processes which were heretofore judged impossible. The entanglement among university, government and industry sometimes makes one indistinguishable from the other. The classical boundary between pure and applied science is now fuzzy. The mores of aeronautical scientists are frequent scientific meetings, trips to Washington,

piles of research reports, purchase requests and contracts, and long lists of publications.

THE FUTURE.

Certain trends in the aeronautical sciences seem evident. Society still attaches much importance to the improvement of flight vehicles. They are still viable generators of creative spirals in which the underlying aeronautical sciences are improved and expanded by a measurable amount during the characteristic development time of a new machine. Whether we like it or not, big projects and large laboratories are here to stay. They have proven effective instruments to their government and military sponsors. Most projects or laboratories need an over-all goal which will carry the average worker through the humdrum research activities of each day. The research worker in the aeronautical sciences may represent any one of the branches of physical science and engineering. Hopefully new breeds can be developed who can represent more than one.

This is not to say that the day of the solitary inventor or the professor working alone with his students is gone. Whereas this type of activity once constituted a large part of research, it now becomes a small fraction. Universities are the custodians of such activities, and they must be mindful lest they trade this precious heritage away. Where it is all going to still is unclear. Most of the pressures which have shaped the present are still acting.

Perhaps the viewpoint which is required for effective research in the aeronautical sciences could be summarized by paraphrasing an introductory sentence in Kelvin and Tait's "Natural Philosophy" to read—

> "Neither seeking nor avoiding scientific or mathematical exercitations, we enter into problems solely with a view to possible usefulness."

Physics, General

(See Rev. 3408)

Analytical Methods in Applied Mechanics

(See also Revs. 3410, 3413, 3421, 3426, 3433, 3436, 3440, 3454, 3459, 3460, 3489, 3498, 3536, 3719, 3767, 3787, 3828, 3857, 3869, 3907, 3913)

3398. Fritscher, O., Calculation of complex roots of algebraic equations as a supplement to Gräffe's method (in German), *Öst. Ing.-Arch.* **14**, 1, 68–75, 1960.

Paper contains a method for the numerical solution of algebraic equations. It presents a supplementary procedure on the numerical method of Graeffe, for the calculation of the arguments of complex solutions of algebraic equations.

The method has the advantage, in comparison with other similar methods, that it is independent of the number of multiplicity of roots, it can be applied without restriction on equations with complex coefficients and it does not necessitate a supplementary iteration procedure, similar to that used in the method of Graeffe. Method is based on the fact that two complex conjugate numbers of value one are reciprocal to one another. By applying this principle and by using the solutions of equation given by the method of Graeffe, a new equation can be formulated which has all its roots for a certain value common with the first equation. Then, the greatest common divisor of these two equations can be found by a rational method of calculation, and the arguments of the corresponding roots are determined.

By a convenient transformation and by substitution of new variables, the amount of calculation can be reduced considerably. If all the coefficients of the equation are real, then the grade of equations, of which the greatest common divisor must be determined, is reduced to one half. In case of an equation with complex coefficients the determination of the roots is at least obtained through real equations.

Finally, a procedure of correction of eventual errors, introduced by the rounding of values during the determination of the greatest common divisor, is presented and three illustrative examples of the application of the method are elaborated.

P. S. Theocaris, Greece

3399. Clerc, D., Programming of the method called "Method of extended matrices" for determining eigenvalues (in French), *Rech. Aéro.* no. 76, 53–55, May/June 1960.

Book—3400. Ostrowski, A., Lectures on differential and integral calculus [Vorlesungen uber Differential- und Integralrechnung], Vol. 1, 2nd ed. Basel, Birkhäuser Verlag, 1960, 330 pp. Fr. 35.

Excellent organization, clarity and precision, illuminating examples, elegant technique and wise choice of material are only *some* of the merits of this volume. Opposed to these are an absence of exercises (to appear in a separate book), a mild ornateness of German literary style, and a failure to point out that the Archimedean property (in the book an axiom) of the real number system is a consequence of the completeness (axiomatized in the book as a "separation" law) of the system. Scholarly and historical footnotes are found throughout. This book is for serious and well-trained mathematics students, who will profit from a reading.

B. R. Gelbaum, USA

3401. Hahnemann, H. W., General method for the application of power series for integral powers to the solution of differential equations (in German), *Forsch. Geb. Ing.-Wes.* **26**, 5, 153–171, 1960.

Solving an ordinary differential equation by means of (integral) power-series expansions generally involves a great amount of calculation, especially when the convergence is slow. Author gives a general scheme valid for a wide class of equations which reduces the length of the procedure by the use of appropriate tables. A number of examples are given.

R. Conti, Italy

Book—3402. Forsythe, G. E., and Wasow, W. R., Finite-difference methods for partial differential equations, New York, John Wiley & Sons, Inc., 1960, x + 444 pp. $11.50.

Book is divided into four parts. The introductory chapter deals with classification of partial differential equations and with a brief description of usual automatic computing systems. Part 1 is concerned with hyperbolic equations. Methods of solving difference equations both for initial and boundary-value problems and questions of stability and convergence of the used finite difference approximations are discussed. Application to a simple problem of shock waves in an isentropic, one-dimensional gas flow is added. Part 2 treats parabolic equations. Particular attention is paid to stability and convergence conditions of the approximate solutions, obtained by means of various finite difference methods. Nonlinear problems are also briefly considered.

Part 3, involving elliptic equations, is the most extensive. After describing some typical technical problems leading to elliptical partial differential equations, the most important results of the classical theory with relation to variational formulations, further concepts of self-adjointness, of interface conditions and of maximum principle are introduced. Discretization of solved prob-

lems, various types of nets and boundary conditions, the application of the variational method of setting up difference equations (diffusion of a neutron-group in a two-dimensional reactor) and further methods of solving difference equations, including relaxation as well as overrelaxation, are treated. A great deal of this part is concerned with considerations on the estimation of the discretization and round-off errors where, besides other methods, a probabilistic one is also introduced. Solution of eigenvalue problem is shown on the membrane oscillatory equation. The upper and lower bounds of eigenvalues are given and numerical solution is indicated. Brief description of the numerical computation of difference equations on automatic computers with respect to the required time is discussed.

The concluding Part 4 deals with initial-value problems in more than two independent variables. Solution of wave propagation and meteorological forecast are briefly treated. Fourier's method of solving differential and difference equations is discussed with particular respect to convergence and stability conditions.

Book gives an excellent survey of the most important achievements developed in the field of difference equations. Though not being exhaustive and having a comparatively difficult topic, it is written very clearly so that it could be used as a very good textbook, A rich list of literature enables a detailed study for specialists. Book can be recommended to a wide group of readers, who wish primarily to understand modern numerical analysis based on the use of difference equations.

V. Kopriva, Czechoslovakia

3403. Boillat, P., On the necessity of three independent physical actions to justify the existence of three complementary terms in second-order equations (in French), *C. R. Acad. Sci. Paris* **250,** 19, 3106–3107, May 1960.

Book—3404. Colombo, S., Mellin and Hankel transformations [Les transformations de Mellin et de Hankel], Paris, Centre National de la Recherche Scientifique, 1959, 99 pp.

This small book on integral transformations is one of the monographs of "Centre d'Etude Mathematiques en vue des Applications." Book consists of five chapters. Chapter I (Introduction to the study of integral transformations) gives a brief review of the Laplace-Fourier transformations. Chapter II (Mellin transformation) and Chapter III (The reciprocal formulae of Hankel) deal with the principles of the corresponding transformations. Chapter IV (Applications to the integration of partial difference equations) and Chapter V (Integral equations of the mixed type) illustrate the principles obtained in the preceding chapters. The bibliography at the end of the book is by no means complete.

O. Gurel, USA

Book—3405. Cashwell, E. D., and Everett, C. J., A practical manual on the Monte Carlo method for random walk problems, Vol. 1, New York, Pergamon Press, Inc., 1959, ix + 153 pp. $6.

Book describes Monte Carlo methods used for electronic computation of the collision problems for neutrons and photons in bulk matter surroundings of different shapes. The computer programming is subdivided into a set of blocks each of which handles a well-defined phase of the problem, thus providing a model of well-organized computation work. A detailed description is given of how actual particle-behavior simulation is used to obtain computer solutions to this class of problems.

Although basically intended for the guidance of people who are interested in particle collision problems the book will also serve those who are interested in computer simulation of other kinds of collision or target hit problems. It may also be of some interest to those who are interested in the technique of simulation in connection with any class of applications.

B. Langefors, Sweden

Book—3406. Gelfand, I. M., and Shilov, G. E., Generalized functions and mathematical operations on them [Obobshchennyie funktsii i deistvyia nad nimi], 2nd ed., Moscow, Gos. Izdat. Fiz.-Mat. Lit. 1959, 470 pp. 14.90 r.

This is the introductory volume of a series of books devoted to the theory and applications of the generalized functions which are steadily growing in significance for various branches of applied mathematics, advanced engineering and theoretical physics. The well-known difficulties at defining such objects as the delta function and others have caught the attention of mathematicians and the results appear nowadays as an elegant theory of generalized functions based upon the modern methods of functional analysis. The present volume gives not only an excellent account of this theory but it brings also many valuable results which are of immediate physical and technical significance.

The subject is divided into three extensive chapters. First of all come fundamental difinitions, differential and integral calculus of generalized functions, some problems of regularization, the notion of convolution and the role of generalized functions in the theory of differential equations. The following chapter deals with Fourier transforms of generalized functions and with related problems of mathematical physics. The last main part has for subject some special types of generalized functions, such as various functions concentrated on a smooth surface, generalized functions associated with a quadratic form, homogeneous functions, etc.

The presentation is clear, vivid and quite accurate from mathematical viewpoint. Careful print and a ridiculously low price will insure a wide distribution of this fine volume, which is sure to be translated into other languages. Such works do not need any recommendation.

V. Vodicka, Czechoslovakia

3407. Bertrais, J., Optimum of an addition or of a product of functions (in French), *C. R. Acad. Sci. Paris* **250,** 12, 2115–2117, Mar. 1960.

Book—3408. Resnick, R., and Halliday, D., Physics for students of science and engineering: Parts 1 and 2, New York, John Wiley & Sons, Inc., 1960, xiv + 554 pp. + appendixes. $6; xiv + 471 pp. + appendixes. $6.

Part 1 is a rigorous treatment of undergraduate physics presenting the classical topics of solid and fluid mechanics, sound and thermodynamics with such modern topics as kinetic theory and wave mechanics. The treatment of each subject is analytical in nature requiring concurrent course in calculus. Modern examples are used to illustrate the discussion and results of experimental investigations are given to reinforce theory.

The material is presented in a logical manner with good use of illustrations. A number of numerical examples are used along with algebraic solutions. An introduction to vector notation and vector algebra is included so that vector quantities can be used in the study of mechanics and motion. The unifying principles and concepts of physics and their application to engineering problems are stressed throughout the material. Discussion questions and numerical problems are given in adequate numbers at the end of each chapter. Tables of fundamental constants, physical data, conversion factors and selected mathematical data are given in the appendices.

Part 2 presents the classical topics of electricity and light with such modern topics as atomic, nuclear, and quantum physics. The comments on Part 1 on general approach, use of examples, problems and appendices, are also applicable to Part 2.

R. G. Nevins, USA

Computing Methods and Computers

(See also Revs. 3398, 3401, 3402, 3405, 3425, 3426, 3451, 3523, 3616, 3767, 3857)

Book—3409. Guest, P. G., Numerical methods of curve fitting, New York, Cambridge University Press, 1961, xiv + 422 pp. $15.

The first part of the book deals with the treatment of observations of a single variable; the second with the fitting of straight lines; and the third with the fitting of polynomials and special types of curves. An ample and up-to-date bibliography of the most important books and original papers on numerical computation methods is presented at the end and serves as a very valuable reference.

This book brings together many different approaches to this special subject which were scattered in the literature and illustrates each method presented with many numerical examples. It will be useful and helpful to research workers and students and, in general, to those interested in the subject of methods of reducing sets of observations and of fitting curves to numerical data. Another valuable aspect of this book is that full derivations are given of the formulas used. E. G. Volterra, USA

3410. Keller, H. B., Special block iterations with applications to Laplace and biharmonic difference equations, *SIAM Rev.* **2,** 4, 277–287, Oct. 1960.

Iterative methods are considered for numerical solution of the linear equations $M\phi = L$ where the coefficient matrix M is of special form common to finite-difference solution of elliptic and hyperbolic partial differential equations. Method studied involves decomposition of M, and paper presents theorems and proofs for selection of decomposition parameters necessary and optimum for convergence. Class of solutions considered employs simultaneous improvement (block iteration), and author notes that, for the two applications given, schemes with better convergence exist which make use of continuous improvement of the unknown ϕ's.

H. M. Voss, USA

3411. Kolesnikov, L. A., Numerical method of successive approximations for the investigation of finite displacements of bent bars subject to complicated loads (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **26,** 228–235, 1958.

A full numerical example concerning the title problem is given and good agreement with experimental results is found.

By the method used, any integrodifferential equations of the type

$$EI\vartheta_s = M[s, \vartheta, x, y, \int q(x, y_s)\,\varphi(x, y_s)\,ds, P, m]$$

or

$$EI\vartheta_{ss} = Q[s, \vartheta\, x, y, \int q(x, y)\,\varphi(x, y)\,ds, P, m]$$

can be solved numerically. Owing to the existence of an upper and a lower limit for the numerical solution, it can be found with any required exactness. A. Werfel, Israel

3412. Kudrievtsev, A. L., On the possibility of the application of electronic digital computers to one of the approximate methods for obtaining conformal maps, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24,** 2, 367–371, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N.Y.)

This note deals with a method of inscribing the largest possible semi-circle in a region of definite shape. Knowledge of this method ensures the possibility of the application of electronic digital computers for the conformal mapping onto regions approximating the upper half-plane. This work is related to that of Lavrent'ev and Shabat. Use is made of one of the reflections, executed by the Zhukovskii function.

From author's summary

Analogies

(See also Revs. 3716, 3788, 3869)

3413. Dyer, I., Moment impedance of plates, *J. Acoust. Soc. Amer.* **32,** 10, 1290–1297, Oct. 1960.

The moment impedance for the vibration of an infinitely extended plate is theoretically determined including the effects of transverse shear deformation and rotary inertia. Author shows that the effects of transverse shear may be important even for thin plates. B. Smilg, USA

3414. Zaid, M., and Ryder, F. L., Electrical analogue to a celled tube subjected to flexure and torsion—a method of solution without formulating the structural equations, *Aircr. Engng.* **31,** 362, 94–100, Apr. 1959.

Methods based on theorem of Castigliano and principle of least power for electrical circuits, as previously discussed by Ryder [*J. Franklin Inst.* **254,** p. 47, July 1952 and *Trans. ASCE* **119,** 1046–68, 1954], are extended to problem indicated by title. Numerical example for two-celled box section given.

F. J. McCormick, USA

Kinematics, Rigid Dynamics and Oscillations

(See also Revs. 3405, 3437, 3451, 3519, 3521, 3618, 3630, 3639, 3857, 3860, 3864, 3871)

3415. Bottema, O., Loci of a remarkable 12-bar linkage (in German), *Öst. Ing.-Arch.* **14,** 3, 218–222, Oct. 1960.

An analysis is made of the curves generated by the moving hinge pivots of a twelve-bar mechanism (described by W. Wunderlich: "Ein Merkwurdiges Zwölfstabgetriebe," *Öst. Ing.-Arch.* **8,** 224–228, 1954; AMR **8**(1955), Rev. 1555); which can be regarded as a parallel projection of the edges of a parallelopiped. If one of the edges is held fixed the degree-of-freedom of the mechanism may change from two to one upon passing through the folding position, provided certain parallelogram configurations transform to anti-parallelogram configurations. Depending upon which of three types of links are held fixed, certain of the moving hinge pivots are shown to describe fourth- or sixth-degree algebraic curves, whose equations are discussed. In the particular configuration consisting of two parallelograms and four anti-parallelograms it is shown that the distances between four sets of hinge pivots remains constant so that by appropriate added links a sixteen-bar mechanism can be obtained.

Reviewer believes investigations of mechanisms exhibiting instantaneous or permanent "critical forms" relative to the degrees-of-freedom—such as above—provide new insight into the nature of linked mechanisms. F. Freudenstein, USA

3416. Brewer, R. C., Synthesis of epicyclic gear trains using the velocity ratio spectrum, *ASME Trans.* **82** B (*J. Engng. Industry*), 3, 173–178, Aug. 1960.

For a simple epicycle train, the controlling element is almost invariably fixed, i.e., prevented from rotating by being connected, in some way, to the frame. Such trains are easy to synthesize because there are a limited number of variations of the three basic elements and, normally, six equations will define all possible velocity ratios. For a compound epicyclic train, the number of equations is considerably increased.

A method of synthesizing compound epicyclic trains is developed using the concept of a velocity ratio spectrum. To facilitate the application of this concept, only one train in a compound

epicyclic train is regarded as basic; all others are considered as merely serving the purpose of modifying the motion of the controlling element in the basic train.

From author's summary

3417. Pollitt, E. P., Some applications of the cycloid in machine design, *ASME Trans.* **82** B (*J. Engng. Industry*), 4, 407–414, Nov. 1960.

Cycloidal motions have many applications in mechanical engineering. The multilobed epicycloid has sharply pointed cusps; therefore, a machine element performing an epicyclic motion can be utilized for performing operations requiring a corresponding action, like folding of flexible materials or feeding of components from a stack. A speed reducer, distinguished by extreme compactness, is based on the use of an epitrochoidal cam. Linkages which perform approximately straight-line motions can be designed so that they approximate the motion of the center of the generating circle of an orthocycloid. From author's summary

3418. Shabonov, P. A., Geometrical interpretations for the problems of the motions of a ponderous, solid body possessing a single, fixed point (in Russian), *Trudi Irkutskago In-ta* **15,** 140–163, 1957; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3458.

The major part of the paper consists of an exposition of the familiar results of Poinsot, Zhukovskogo and Delannay, on the geometric patterns of motion of bodies in the Euler and Kovalevskii cases. The geometrical interpretation suggested by the authors for the Steklov case consists in rolling an algebraic curve of the fourth order inalterably linked with the body, over a particular, fixed surface, the equation whereof, as indicated by the author, can be determined after eliminating two variables from a system of algebraic equations, of the second to the fourth orders, and connecting four variables. The author makes no attempt to analyze the said curve and surface. The motion in the Bobyler-Steklov case is interpreted as the rolling without slipping of a body-linked plane, over a stationary cone, the generating line whereof is determined by a differential equation. P. V. Kharlamov

Courtesy Referativnyi Zhurnal, USSR

3419. Huang, S.-S., Very restricted four-body problem, NASA TN D-501, 13 pp., Sept. 1960.

Consider three particles of masses m_1, m_2, m_3 which move in a plane as follows: the center of mass, $0'$, of m_2 and m_3 revolves around the center of mass, 0, of the entire system in a circular orbit while m_2 and m_3 themselves revolve around their center of mass, $0'$, also in circular orbits. The motion of a fourth particle of negligible mass is studied in the plane of motion of m_1, m_2, m_3 in a manner similar to that used in the restricted three-body problem (construction of an integral of the equations of motion similar to that of Jacobi in the restricted three-body problem, discussion of the zero-velocity surfaces, their double points and degeneration).

There are some misprints on p. 2.

E. Leimanis, Canada

3420. Kuznetsov, B. G., Generalized virtual displacements, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23,** 4, 963–974, 1959. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Author proposes a generalization of the virtual displacements which are not really displacements but certain functions of the time. They are used in a way somewhat similar to the use of the virtual displacements, and they are determined from a system of differential equations instead of from a system of algebraic equations as in the case of virtual displacements. The author demonstrates the usefulness of these generalized displacements by verifying the Hamilton principle for a motion of a conservative system with certain type of constraints and by applying it to an example of the motion of a material point with a given constraint on its velocity. T. Leser, USA

3421. Thomson, W. T., Shock spectra of a nonlinear system, *ASME Trans.* **82** E (*J. Appl. Mech.*), 3, 528–534, Sept. 1960.

A one-dimensional damped oscillatory system with simple nonlinear spring composed of two linear parts describing linear growth and following saturation is studied. Nonlinear mathematics can thus be avoided. The peak reponse under different pulse excitations is analytically calculated. For the cases of the step- and delta-function excitation and damping as parameter the shock spectra are given. The rectangular pulse excitation is treated also but the shock spectra are discussed for zero damping only with pulse duration as parameter. Finally, a general procedure for a pulse excitation of arbitrary form is given and applied to both rectangular and sine pulse of differing pulse duration. Phase-plane plots are used in a generalized manner throughout the investigation. F. Engelmann, France

3422. Lur'e, A. I., Unsteady motion in quasilinear, independently oscillating systems (in Russian), *Trudi Leningrad Politekhn. In-ta* no. 192, 98–108, 1958; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3498.

An analysis of a quasi-linear system of $(n + 2)$ first-order equations

$$\dot{y}_s = q_{s1}\,y_1 + \ldots + q_{s1}y_1 + \cdots q_{2n+2}\,y_{n+2} + \mu Y_s(y_1, \ldots, y_{n+2})$$

$$s = 1, \ldots, n+2$$

with the constant coefficients q_{sk}. The quantity μ is a small parameter. The determining equation $\|q_{sk} - \delta_{sk}\lambda\| = 0$ has a pair of purely imaginary roots of the form $\pm ri\omega$, where $r = 2, 3, \ldots$ A linear, nonspecific transformation is applied to isolate the equations for the noncritical variables $x_1, \ldots, x_n$, and the critical variables x and y, after which the complex variable $z = x + iy$ is derived. In the new variables, the equations have the following form:

$$\dot{x}_s = p_{s1}x_1 + \ldots + p_{sn}x_n + c_s z + \bar{c}_s\bar{z} + \mu X_s(z, \bar{z}, x_1, \ldots, x_n), \quad s = 1, \ldots, n;$$

$$\dot{z} = i\omega z + \mu Z(z, \bar{z}, x_1, \ldots, x_n);$$

$$\dot{\bar{z}} = -i\omega\bar{z} + \mu\bar{Z}(z, \bar{z}, x_1, \ldots, x_n).$$

The function Z and the constants c_s are complex quantities. The solution of the system is sought in the form of series:

$$z = re^{i\psi} + \mu\omega_1(r, \psi) + \mu^2\omega_2(r, \psi) + \ldots$$

$$x_s = t_s z_s + \bar{t}_s\bar{z}_s + \mu x_s^{(1)}(r, \psi) + \mu^2 x_s^{(2)}(r, \psi)\ldots,$$

in which t_s are complex constants; $w_k(r, \psi)$, complex, and $x_s^{(k)}(r,\psi)$ real, functions of r and ψ with a period of 2π. The quantities r and ψ are slowly-varying time functions determined by the equations:

$$\dot{r} = \mu R(r);$$

$$\dot{\psi} = \omega + \mu\Omega_1(r) + \mu^2\Omega_2(r + \ldots$$

Comparison of the coefficients for identical powers of the parameter μ furnishes differential equations for the consecutive determination of the functions $w_k(r, \psi)$. The constants t_s are found from a system of linear, algebraic equations. The sequence of operations for the construction of the solution is described. In the first instance, the constants t_s are found, then the functions $x_s^{(1)}$. From the condition of the existence of a periodical solution of w_1, $R(z)$ and $\Omega_1(r)$ are determined. This determines w_1 with an accuracy to the additive term $C_1(r)e^{i\psi}$. The periodicity condition of the function w_2 determines $C_1(z)$ and $\Omega_2(r)$. In determining $C_1(r)$, the initial condition Im $z = 0$ for $\psi = 0$ is also applied. Next, the

functions $x_s(2)$, etc., are found, it being assumed that $R(z)$ is not identically transformed to zero. For the periodical solutions of the initial system with a time period of $2\pi/\psi$, transforming for $\mu = 0$ with periodical solutions of the generating system with the period $2\pi/w$, the equation of the amplitudes $R(r^*) = 0$ is derived. These solutions coincide with the solutions by the Poincare method. The solution of the initial problem with an accuracy within quantities of the order of μ is further examined in detail. This furnishes an equation for ψ which is accurate within terms of the order of μ^3. All calculations are demonstrated on the example of a Van-der-Pol equation.

$$\ddot{x} + \mu(1 - x^2)\dot{x} + x = 0$$

A. P. Proskuryakov
Courtesy Referativnyi Zburnal, USSR

Instrumentation and Automatic Control

(See also Revs. 3509, 3632, 3756, 3805, 3862, 3869, 3872, 3874)

3423. Gafanovich, M. D., Consumption-measuring differential manometers with automatic correction for several gas parameters, *Measurement Techniques* no. 10, 810-816, Aug. 1960. (Translation of *Izmeritel'naya Tekhnika, USSR* no. 10, 47-50, Oct. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

An instrument to measure rate of gas flow, continuously corrected to standard conditions of temperature, pressure and moisture content, is described. Pressure, temperature and pressure differential are sensed with appropriate transducer elements; moisture content, through lack of suitable sensing elements, is introduced manually.

Corrections to the flow rate caused by departure of temperature, pressure and humidity from standard condition are made by means of a moving coil device described as a ferrodynamic transducer. It is claimed that this type of compensation flow-meter is superior to similar instruments using sliding-contact resistors, which are subject to rapid wear, oxidation, dirt when used in the atmosphere common to chemical and other such industrial plants. Less than 4 per cent error in flow measurement is predicted for the extreme conditions of temperature, pressure and humidity.

E. K. Parks, USA

3424. Zhokhovskii, M. K., A manometer with an effective piston area unchanged by pressure, *Measurement Techniques* no. 8, 593-595, July 1960. (Translation of *Izmeritel'naya Tekhnika, USSR* no. 8, 14-15, Aug. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Object of paper was to determine conditions under which the effective area of piston of a manometric piston gauge is independent of pressure. From analysis of deformation of piston and cylinder a feasible physical arrangement is proposed. However, no experimental evidence is presented to confirm whether the arrangement leads to a significant reduction in measurement error. No reference is made to related work published in English. In this connection the summary by Singh [D.S.I.R., Merl Fluids Report no. 66, Feb. 1958] should be consulted. R. A. A. Bryant, Australia

3425. Orurk, I. A., Synthesizing the elements of linear automatic control systems, *Automation and Remote Control* **20,** 12, 1550-1557, June 1960. (Translation of *Avtomatika i Telemekhanika, USSR* **20,** 12, 1595-1602, Dec. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

A method of synthesis based on numerical integration of a system integral equation is proposed. The linear differential equation of the system in operational form is modified by introduction of an auxiliary function, a high-order derivative of which is the time-function system response. Expanding the auxiliary function in a Maclaurin series yields a Volterra integral equation of the second type in the response function. This equation is integrated using a trapezoidal formula for calculating the integral. The resulting algebraic equations establish linear relationships between system parameters and particular values of the time response. These equations are used as the basis for synthesis.

The entire numerical process reduces to the calculation of polynomial coefficients, solution of linear algebraic equations, and evaluation of polynomials for certain values of a variable. The method is easily adaptable to electronic computers. An appendix gives several numerical examples. R. B. Grant, USA

3426. Rozonoer, L. I., L. S. Pontryagin maximum principle in the theory of optimum systems: Parts 1, 2, and 3, *Automation and Remote Control* **20,** 10, 1288-1302, June 1960; **20,** 11, 1405-1421, June 1960; **20,** 12, 1517-1532, June 1960. (Translation of *Avtomatika i Telemekhanika, USSR* **20,** 10, 1320-1334, Oct. 1959; **20,** 11, 1441-1458, Nov. 1959; **20,** 12, 1561-1578, Dec. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Rozonoer apparently is one of Russia's engineer-mathematicians whose function it is to bring the mathematicians' flights to earth and make them meaningful to engineers. A rather good presentation is given of the "Pontryagin maximum principle" in the problem of optimum synthesis and control.

An interesting feature is the derivation of the relationship between the maximum principle and Bellman's dynamic programming. The first leads to a set of equations identical with Hamilton's equations of analytical mechanics, while the second is shown to give rise to the Hamilton-Jacobi partial differential equations for the same problem.

The translation is clear, although there are many minor typographical errors. The vocabulary and especially the punctuation are sometimes surprising. M. Shinbrot, USA

3427. Kryzhanovskii, O. M., and Knutsevich, V. M., Transients in optimal control systems, *ARS J.* **30,** 1, 86-92 (Russian Supplement), Jan. 1960. (Translation of *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Energetika i Avtomatika* no. 3, 32-42, 1959.)

Paper studies transients in optimal control systems for different conditions. It is useful to outline procedure first. First, authors formulate the differential equations (d.e.) of (1) servomotor; (2) linear part of controlled object; (3) nonlinear extremal characteristic; (4) law of control (from measuring instrument). In this way some intermediate variables appear which are later eliminated; thus a linear d.e. for the transient motion in the controlled coordinate is obtained; it is ultimately discussed with reference to the corresponding phase trajectories. The subsequent analysis develops from this point, recalling that the optimal trajectories are parabolic arcs in the phase plane. If the proportional element is replaced by a relay, the last term in the final d.e. contains Signum as a factor; this results in a piecewise parabolic (PWP) law either converging to zero or to an analogous (PWP) limit cycle according to the relay parameters.

The next case deals with a logical action control; the procedure is the same but results are different; here the boundary of the phase plane (for $x > 0 \longrightarrow x < 0$ transitions or vice versa) is limited by hyperbolic branches but the qualitative aspect (of PWP trajectories) is the same. Still another case appears when the control law contains a term with $\dot{x}$ which influences the damping.

A number of other cases are investigated following the same procedure; in some cases PWP trajectories degenerate into straight lines. Finally, the effect of time lags is studied, but in this case the problem becomes more complicated, being of the difference-d.e. type. N. Minorsky, France

3428. Follinger, O., The number of turns of the root locus curve (in German), *Regelungstech.* **8,** 9, 308–311, Sept. 1960.

In this article a formula is derived for the number of encirclements of the Nyquist plot around the—1 point in the complex plane of the open loop gain. Three conclusions are drawn:

(1) The Nyquist criterion can be illustrated in a general form.

(2) The Nyquist plot for the open loop gain enables the number of poles of the closed loop system in the right-hand half of the complex frequency plane to be found, an important criterion for the stability of multiple loops.

(3) The number of the zeros in the right-hand half-plane of a parallel arrangement can be ascertained, thus supplying the answer to the question whether it is a minimum phase system.

Finally, the author demonstrates, with the help of an example, how to determine the number of encirclements.

From author's summary

3429. Schwarze, G., Rough calculations of control loops having control lines with compensation performed on the basis of characteristics of the singular elements (in German), *Automatisierung: Z. Messen, Steuern, Regeln* **3,** 9, 385–393, Sept. 1960.

3430. Taft, V. A., On the analysis of the stability of the periodic modes of operation in nonlinear control systems with many degrees of freedom, *Automation and Remote Control* **20,** 9, 1132–1140, May 1960. (Translation of *Avtomatika i Telemekhanika, USSR* **20,** 9, 1163–1170, Sept. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

In order to investigate the stability of a periodic mode of a nonlinear control system, the equation for small deviations from the periodic motion is considered. This equation is separated into its Fourier components and then yields an infinite set of equations. The determinant of this set should vanish, which leads to the characteristic equation of the system. In analogy with Hill's determinant, the present determinant can also be reduced to a characteristic equation in finite form. By applying the Mikhailov stability criterion, which is known in the West as the Nyquist criterion, the stability of the periodic mode is investigated.

A. I. van de Vooren, Holland

3431. Don-Tri, H., Contribution to the study of nonlinear systems—Theoretical study of the problem of automatic speed regulation in automatic pilots (in French), *Automatisme* **5,** 5, 177–183, May 1960.

Classical method of analysis is applied to a particular system incorporating three "on-off" relays, with unsymmetrical time delays. Method gives

(1) Ratio of times in two operating states;

(2) Frequency of oscillation;

(3) System time constants.

Conditions for approximately linear behavior are also obtainable. Full account of theory is given, together with worked example and graphed results. Method is applicable to analysis of other complex relay-operated systems and paper is of value to anyone concerned with design of such systems.

R. H. Macmillan, England

3432. Krinets'kii, I. I., A simplified analysis of the steadiness of control of nonlinear systems (in Ukrainian), *Avtomatika, Kiev* no. 1, 44–49, 1958; *Ref. Zh. Mekh* no. 4, 1959, Rev. 3497.

A method is described for the approximate analysis of the control stability of nonlinear systems incorporating one simple nonlinear characteristic of the regulating servomechanism. The method is illustrated on a number of concrete examples.

M. E. Tenchenko

Courtesy Referativnyi Zhurnal, USSR

3433. Anosov, D. V., Stability of the equilibrium positions in relay systems, *Automation and Remote Control* **20,** 2, 130–143, Jan. 1960. (Translation of *Avtomatika i Telemekhanika, USSR* **20,** 2, 135–149, Feb. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

A stability investigation for the relay system described by the system of nonlinear equations

$$\dot{x}_i = \sum_{j=1}^{n} a_{ij}x_j + k_i \operatorname{sign} x_1, \quad i = 1,2,\ldots,n.$$

The author carefully describes the physical situation and then demonstrates a stability theorem ($r \leq 3$ should be replaced by $r \geq 3$) previously stated by Tsypkin. The proof makes use of a Lyapunov function and work of Pontryagin and Boltyanskii.

R. E. Kalaba, USA

3434. Matveev, P. S., Synthesis of servosystem correcting devices in the presence of noise, *Automation and Remote Control* **20,** 6, 698–705, Feb. 1960. (Translation of *Avtomatika i Telemekhanika, USSR* **20,** 6, 721–728, June 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

A linear feedback control system contains within its loop a known controlled element and an unknown controller. The controlled element input is contaminated by a random disturbance $u(t)$. The over-all system input contains three components: $g(t)$, a given function of time, $m(t)$ a random message, and $n(t)$ a random disturbance. $m(t)$, $n(t)$ and $\omega(t)$ are stationary, have zero mean values, are assumed to be not correlated and have known spectral densities. Object of paper is to determine the transfer function of the controller which minimizes mean square error between actual system output and desired output due to $g(t)$ and $m(t)$.

Solution involves rephrasing of the problem in terms of an equivalent open loop system and determination of the optimum over-all system impulse response $k(t)$ (misleadingly translated as "pulse transfer function"). Knowledge of controlled-element transfer function then enables controller transfer function to be obtained.

The method involves determination of conditions for mean value of error to be zero and then derivation of an integral equation which $k(t)$ must satisfy for mean square error to be minimum. Solution of integral equation and application of above conditions lead to explicit expression for $k(t)$. Method is illustrated by an example of the synthesis of the controller for an automatic stabilization system.

Paper is heavily dependent on several earlier papers in Russian literature including Matveev [AMR **13**(1960), Rev. 5592], and Batkov and Solodovnikov, [*Automation and Remote Control* **18,** no. 5, May 1957].

R. J. Kavanagh, Canada

3435. Kukhtenko, V. I., On designing correcting circuits for automatic control systems in accordance with the mean-square-error criterion, *Automation and Remote Control* **20,** 9, 1151–1159, May 1960. (Translation of *Avtomatika i Telemekhanika, USSR* **20,** 9, 1180–1187, Sept. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

This paper deals with the least-squares smoothing of a polynomial signal in noise, a problem treated originally by Zadeh and Ragazzini [*J. Appl. Phys.* **21,** p. 695, 1950]. It is known that the optimal linear smoothing filters in this case are nonrealizable, strictly speaking. Present paper is a continuation of an earlier one by the same author [title source **17,** 5, May 1956], both treating the problem of finding the best realizable filter. It is shown that the problem, like its above-mentioned prototype, is a variational problem with constraints, but that the number of constraints is greater. The solution is reduced to that of a Wiener-Hopf equation. An illustrative example is worked out.

F. R. Drenick, USA

3436. Andreev, N. I., A general condition for an extremum of a given function of the mean-square error and the squared mathematical expectation of the error of a dynamic system, *Automation and Remote Control* **20,** 7, 807–812, Mar. 1960. (Translation of *Avtomatika i Telemekhanika, USSR* **20,** 7, 833–836, July 1959 by the Instrument Society of America, Pittsburgh 22, Pa.)

The derivation is given for the condition for an extremum, and also for the greatest or least, value of some function I of the mean-square error and the squared mathematical expectation of error in approximating a random function. The general condition obtained is applied to the problem of choosing an optimal nonlinear integral operator.

From author's summary

3437. Rogers, M., and Shapiro, G., Closed-loop flip-flop control systems, *J. Aerospace Sci.* **27,** 11, 841–853, Nov. 1960.

The rolling behavior of an airframe subject to a special type of on-off control is analyzed. It is assumed that the autopilot calls for a switch in the control torque from one extreme to another whenever the quantity $\theta + t_L\dot{\theta}$ passes through zero (θ is the roll angle, t_L a lead time). The switch however is not executed instantaneously, as is usually taken for granted, but after a delay t_D, and even then the transition is assumed to be gradual, i.e., linear in time and consuming a period t_R. The characteristics of the limit cycle of the free-running system are examined as functions of the three time constants t_L, t_D, t_R, by phase plane plot, analog computer, and explicit solution.

R. F. Drenick, USA

3438. Tsipkin, Ya. Z., Some problems in the synthesis of automatic pulse controllers (in Ukrainian), *Avtomatika, Kiev* no. 1, 3–19, 1958; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3520.

Automatic pulse-controller systems are investigated; the relationships between the transfer functions, frequency and time characteristics of such systems and their continuous parts, on which the synthesis is based, are described. The conditions are determined for the optimum process which would ensure the minimum and finite duration of the transient process for a given action signal, and the minimum, mean-square error in random actions. Analytical and graphical methods are described for the synthesis of optimum pulse-control systems, which can be realized by applying continuous or pulse corrections. An example of pulsed correction is shown, performed by a numerical computer with preset programming.

M. E. Temchenko

Courtesy Referativnyi Zhurnal, USSR

3439. Neumann, B., A contribution to regulation by impulses (in German), *Regelungstech.* **8,** 10, 348–352, Oct. 1960.

A three-step action relay system with delayed feedback and equipped with an impulse emitter for integral control can be considered, by introducing certain simplifications, as a linear proportional-plus-integral controller.

From author's summary

Book—3440. Automatic controls [Avtomaticheskoe regulirovanie], Moskva, Mashgiz, 1960, 139 pp. 3 r 75 k. (Paperbound)

This book is a collection of six papers dealing with automatic control of boilers and some theoretical and experimental investigations of steam turbine control elements. The collection is intended for design specialists in the field of automatic controls.

The first paper by V. D. Piven' derives theoretical conditions for autonomous behavior of self-regulating objects by utilization of double sample regulators with an auxiliary rate sampling of the controlled parameter variation.

The second paper by V. I. Senkin and V. S. Poborchii investigates the dynamics equations for a drum steam boiler with natural circulation including conditions below the surface of evaporation. A comparison is made between the derived and the experimental results taking into account circulation dynamics.

The third paper by I. I. Aizenshtat considers a new scheme for automatic temperature control in drum boilers utilizing sampling of steam temperature ahead of the cooler. Derived are equations for a multi-sample tempearture regulator which are used in analyzing two systems of temperature control.

The fourth paper by V. S. Poborchii investigates the dynamics of mechanized stokers and their effect on boiler control problems. An example is given using the derived equations in studying a transient feed process. The theory is in good agreement with experimental results.

The fifth paper by V. I. Senkin studies self-sustained oscillations in a system for fuel oil pressure control. It is shown that self-sustained oscillations may be induced in the piping by the displacement action of the control valve. The stability conditions as well as the form and period of oscillation are derived by the Luré method. Several practical conclusions are made.

The last paper by A. P. Kirpichev presents the experimental results obtained in the study of clearance port overlapping and leakage effects in a slide-type valve on the sensitivity of an hydraulic servomotor. Many pressure, flow and load conditions were studied and the results plotted. The effects of cylinder leakage were also considered. The conclusions should be of considerable interest to slide valve designers and analysts of hydraulic amplifiers.

Reviewer believes this collection of papers is a valuable contribution to the literature of automatic controls.

V. Chobotov, USA

3441. Armi, E. L., and Kirkpatrick, C. G., Temperature control by means of the Peltier effect, *Aircr. Engng.* **33,** 383, 12–14, Jan. 1961.

A major potential application of the Peltier effect is the thermostating of electronic equipment, modules and individual components. Limitations of size and weight rule out mechanical refrigeration for small cooling units. However, Peltier cooling devices are size-independent in their efficiency and in miniaturized form may be incorporated into heat-generating circuit components. Peltier units can remove heat directly from the source rather than from an external surface and, in addition, these thermodynamically reversible devices permit both heating and cooling. Electronics may thus be thermostated at or below ambient temperature to provide increased reliability and stability. The authors discuss specific applications of Peltier thermostating under development.

From authors' summary

3442. Weller, W., Studies of the superheated steam temperature control of drum boilers operated on a natural circulation system (in German), *Automatisierung: Z. Messen, Steuern, Regeln* **3,** 8, 333–340, Aug. 1960.

3443. Dynamic pressure feedback; controlled damping by use of the Dowty-Moog valve, *Aircr. Engng.* **32,** 376, 171–176, June 1960.

Electrohydraulic servos have been widely applied to the task of precisely positioning heavy loads. Common examples from the military field are radar antenna and rocket engine swivelling drives. In the commercial area large machine tool position controls are a prime example. Even with relatively substantial driving linkages, the inertia of these loads frequently results in low natural frequency of the output load-driver structure. Very commonly this is combined with extremely small natural damping forces. Natural frequencies from 5 to 20 cps with damping ratios in the oder of 0.05 critical are typical.

This combination of resonance with low damping creates a severe stability and performance problem for the electrohydraulic servo drive. Efforts to deal with this problem have centered on in-

troducing artificial damping. In the past this has been done either by use of a controlled piston by-pass leakage path or by use of a load force feedback path. The former technique is simple but wasteful with respect to power and inherently involves serious performance compromises. The latter technique can be arranged to be unassailable on theoretical grounds. However, it leads to severe system complication and large incremental hardware requirements. Questions of a reliability penalty are raised.

A new technique has been developed which possesses all the performance advantages of load feedback without serious increase in complexity. Called Dynamic Pressure Feedback, this technique involves only a modification of servo valve component. It utilizes for feedback purposes the inherently high load forces developed as piston differential pressures, insuring reliable operation. The pressures needed are already available at the valve. No new hydraulic or electrical connections are added.

The performance advantages adduced for the Dynamic Pressure Feedback Servo Valve have been confirmed in carefully controlled comparative tests on a typical load system. Correspondence of test data with analytical prediction is good.

A sufficient number of Dynamic Pressure Feedback Servo Valves have been produced on a pilot production line and installed in several applications in the field to insure producibility and design reliability. From summary

3444. Box, G. E. P., Some general considerations in process optimization, *ASME Trans.* **82** D (*J. Basic Engng.*), 1, 113–119, Mar. 1960.

Author introduces his subject by the statements: "In any consideration of optimization one of the first things which must be decided is what should be optimized.... Objective of ten best expressed in terms of optimizing some *principal* response, subject to certain restrictions." General location of optimum is explored in detail by experiments arranged in patterns appropriate with respect to the variables, and the results are analyzed by least squares in second degree of variables. This can then be transformed by canonical analysis which may reduce the number of variables. Such transformation is of special importance to improve stability of the determination of the optimum by iterative methods of solution.

Against this background, author reviews the methods of evolutionary operation, abbreviated EVOP, which he applied previously to batch processes [*Appl. Statistics* **6**, 3–32, 1957]. When these methods are applied to continuous processes, automatic optimization can be achieved by adjusting the frequency of deliberately induced variations in the process variables so that the signal-to-noise ratio of the response is a maximum. This can be accomplished by simultaneous consideration of the frequency response of the process function and the noise spectrum of the process.

M. A. Mayers, USA

3445. Kaltenecker, H., Methods and applications of extreme-value and extreme-location selection (in German), *Regelungstech.* **8**, 9, 293–297, Sept. 1960.

In some plants it is necessary to measure a variable in various places at the same time. If it is a question of automation the highest and the lowest measured values and the location of measuring are of particular interest. In this article the author discusses the problems involved in the selection of such extreme values and the principal methods applied. Examples of extreme-value selection in existing plants are given. From author's summary

3446. Profos, P., Regulating behavior and controllability of typical controlled plants (in German), *Regelungstech.* **8**, 10, 335–340, Oct. 1960.

Author discusses generally a few properties and relationships describing the regulating behavior in servomechanisms and automatic process controls. He furthermore deals with the possibilities of influencing the transfer characteristics of the controlled plants. The term "controllability" is then studied and, in this connection, an attempt is made to classify the most important types of regulating behavior of the controlled plants falling into the field of application under consideration.

From author's summary

3447. Liubimtsev, Ya. K., The sufficient conditions of stability in a large system of *n* hydraulic basins (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Radiofizika* no. 1, 96–105, 1958; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3494.

An examination of the feeder section of an hydraulic turbine installation consisting of a constant-level head-pond with n regulating basins connected by a common gallery; the first, $n-1$ basins having concentrated resistances (some of these basins can be treated as catchwaters). Applying Lyapunov's second method, the sufficient conditions of large-scale steadiness and unsteadiness are found for such an hydraulic system on the assumption that all the members of this system are unlike and that at its discharge the turbine governor maintains a constant output. For the particular case of two basins the transition at the limit to a differential regulating basin is demonstrated. It is pointed out that for a large number of members, effective calculations require the use of modern, high-speed, electronic computers.

G. V. Aronovich
Courtesy Referativnyi Zhurnal, USSR

3448. Morris, R. V., and Stoeg, C. W., Jr., Multicondition terminal control systems for aircraft, *J. Aerospace Sci.* **27**, 9, 703–711, Sept. 1960.

Paper considers synthesis of a control system which is intended to cause the response of a controlled member to meet several independently specified conditions at a given instant of time. The method is applicable to any constant-coefficient or time-varying linear controlled member. In the case of a touchdown control system for aircraft, this type of control stresses the importance of position and velocity at the instant of touchdown instead of requiring the aircraft to follow a specified final-approach path. The actuating error is the difference between the estimated values of the actual and desired system responses (final response error) at the instant of touchdown. The authors present five principles of operation of a terminal control system for simultaneous control of a response and its derivative together with a possible synthesis procedure for the control equipment. Experimental results obtained from an analog computer are presented, using as the controlled member a model of the vertical motion of a landing aircraft.

S. Z. Dushkes, USA

3449. Rodden, J. J., and Pollak, R. J., Servo control of a variable thrust rocket, *ARS J.* **30**, 10, 964–967, Oct. 1960.

Completed tests of a variable-thrust engine operated in a closed loop formed by feeding back a voltage proportional to chamber pressure to an electrohydraulically actuated injector are described. In effect, a "thrust" servomechanism was created which produces thrust proportional to a voltage input. They demonstrated closed loop thrust response to a voltage command equivalent to a second-order system flat to about 6 cps. It was determined that through proper mechanical design a continuously controlled engine with full-range-throttlability could be produced with a bandpass limited only by the chemical reaction time for fuel ignition.

From authors' summary

3450. Graybar, H. D., Dynamic stabilization of a small body between two equal rotating masses, *ARS J.* **30**, 10, 975–976 (Tech. Notes), Oct. 1960.

3451. Mathews, K. C., Missile orientation errors in command guidance systems, *ARS J.* **30,** 1, 46–50, Jan. 1960.

Some types of command guidance systems utilize tracker data plus the missile roll autopilot control equation to compute missile angular orientation at the command point. In these systems tracker errors, autopilot transient errors and angles-of-attack result in incorrect command transmission and a consequent performance degradation. An analysis is made of command errors and performance degradation resulting from tracker errors and angle-of-attack in two types of command guidance systems employing the roll autopilot control equation for orientation computations. It is shown that much smaller command errors are expected to occur in a system in which the roll autopilot keeps the time integral of roll rate equal to zero than in a system in which the roll autopilot maintains perpendicularity between one wing plane and a fixed inertial reference plane. From author's summary by A. E. Bryson, USA

Tables, Charts, Dictionaries, etc.

(See Revs. 3644, 3950)

Elasticity

(See also Revs. 3424, 3469, 3488, 3495, 3497, 3506, 3523, 3524, 3527, 3541, 3603, 3629, 3785, 3913)

3452. Reiner, M., The stress-strain relation of elasticity and the measure of strain (in English), *ZAMM* **40,** 9, 415–420, Sept. 1960.

Author develops a general stress-strain relation of elasticity, applicable regardless of the strain tensor chosen. The resulting infinite parameter equation is reduced to one of only four parameters in the infinitesimal case. Elementary examples of tension, hydrostatic pressure and simple shear are considered in the analysis. R. E. Miller, USA

3453. Zorski, H., General solutions of the conservation equations in curved spaces, *Bull. Acad. Polonaise Sci.* **7,** 10, 567–571, 1959.

Paper is concerned with solutions of the equation $\nabla_\alpha t^{\alpha\beta} = 0$ in an n-dimensional affinely connected space. Previous known solutions are confined to flat spaces or two-dimensional spaces of constant curvature. A method of obtaining a general solution is indicated. More specialized solutions are considered in greater detail and are interpreted in Riemannian spaces of two or more dimensions. R. Tiffen, England

3454. Singh, A., Stress distributions within solids of revolution (in English), *ZAMM* **39,** 12, 484–495, Dec. 1959.

Author treats symmetric deformation of transversely isotropic medium bounded by two co-axial conical surfaces. Assuming existence of Mellin transform of surface tractions, author obtains formal solution of deformation in terms of Mellin transform of Elliott's functions [*Proc. Cambr. Phil. Soc.* **44,** 1948] and gives simplification of these formal results for the half space. As an example, the half space with uniform surface traction over circular area of the boundary plane is treated and the necessary integrals evaluated to yield the normal stress along the axis of symmetry. C. N. de Silva, USA

3455. Eringen, A. C., and Dunkin, J. W., The elastic half plane subjected to surface tractions with random magnitude or separation, *ASME Trans.* **32** E (*J. Appl. Mech.*), 4, 701–709, Dec. 1960.

First- and second-order moments of the stress tensor are obtained for the elastostatic problem concerning the half-plane subjected to random boundary tractions. The cases treated include the following types of applied surface tractions: (a) A purely random Gaussian load (white noise); (b) concentrated loads of random magnitudes separated by equal intervals; (c) a concentrated load acting at a random location; and (d) concentrated loads of equal magnitudes separated by random intervals.

From authors' summary by D. R. Bland, England

3456. Vlasov, V. V., Application of the method of initial functions to the plane problem of the theory of elasticity for a rectangular region (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 3, 114–125, May/June 1959.

Solution of the plane problem of equilibrium of a long rectangular plate is treated. The solution can formally be applied to some cases of plane deformation too.

In connection with another paper of the author [Izv. MVO, Stroitelstvo i Arhitektura, no. 2, 1958], expressions for displacement- and stress-components are given as a sum of products of four initial functions with certain differential operators.

Three examples are given, treating the question of exact solution of the plane problem for the rectangular long plate with homogeneous boundary conditions on two opposite, parallel sides. In order to satisfy these conditions, a system of differential equations is obtained, determining the form of four initial functions. Expressions for displacement- and stress-components are thus independent of boundary conditions on two other edges of the plate and so a conclusion results, that the given solutions are general solutions for the case of a long plate with two parallel boundaries and two other boundaries having an arbitrary form.

Natalija Naerlovic, Yugoslavia

3457. Bruhl, C., On the analysis of oblique clamped box beams (in German), Dtsch. Versuchsanstalt Luftfahrt, Ber. 18, 80 pp., Apr. 1960.

Paper deals with the stress distribution in box beam systems of the type met with in aircraft swept wings. After reviewing the up-to-date methods for studying such systems, author divides them as follows:

—continuous methods, based on the theory of elasticity, which lead to the solving of some differential equations;

—discontinuous methods, of the type used for studying hyperstatic systems.

Further, Benthem's continuous method is developed, on the basis of which author calculates a model of a 45° sweptback box beam. The deformation in various elements of the model are then examined with the aid of electrical gages. The model was loaded by concentrated forces which led to bending and twisting stresses. Results of measurements show a good agreement with theoretical data.

The study is of particular value for modern aircraft designers.

G. B. Buzdgan, Roumania

3458. Kozesnik, J., A contribution to the theory of state of stress variable with time (in English), *Acta Techn., Czech. Acad. Sci.* no. 5, 389–405, 1960.

Paper discusses the variation of stress around a point assuming that the components of the stress tensor are a sum of components constant in time and harmonically varying components. It is shown that the normal and tangential components vary such that their ends move on ellipses. In the plane case, Mohr's diagram shows ellipses which in certain cases degenerate into circles or straight lines.

The formulas and diagrams obtained are exemplified by particular cases of variation of the principal stress.

M. Misicu, Roumania

3459. Vorovich, I. I., and Kosmodamianskii, A. S., Elastic equilibrium of an isotropic plate, weakened by a series of like curvilinear openings (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 4, 69–76, July/Aug. 1959.

With use of well-known complex-variable techniques, analysis is given of the following problem: an infinite elastic plate, containing an infinite row of geometrically similar and similarly situated holes, and uniformly stressed in simple tension at infinity. Specialization is made to a row of elliptical holes. Detailed numerical results of the distributions of stress are given for various values of the ratio of lengths of ellipse axes (the extreme cases of a crack and a circle being included) and with the tension acting parallel or perpendicular to one symmetry-axis. The present problem is a generalization of the problem for a row of circular holes discussed by R. C. J. Howland [*Proc. Roy. Soc. Lond. (A)* **148**, 471–491, 1935]. An interesting conclusion is the fact the maximum stress for a row of holes can be less than that for an isolated hole. H. G. Hopkins, England

3460. Ufland, Ia. S., Elastic equilibrium of an infite body weakened by an external circular crack, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **23**, 1, 134–144, 1959. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

An exact solution is displayed for the problem of determining the stresses and displacements within an isotropic, homogeneous, elastic medium of infinite extent containing a cut which extends outward from $\xi = \infty$ and which is bounded by the surfaces $\eta = \pm\pi$ (in the toroidal coordinate system for which $0 \leq \xi \leq \infty$, $-\pi \leq \eta \leq \pi$, and $0 \leq \varphi \leq 2\pi$) upon which surface tractions are prescribed. The solution is obtained with the aid of the Papkovich-Neuber representation for displacements, the Mehler-Fock integral transform, and a so-called "special" solution of Laplace's equation.

In reviewer's opinion the paper cannot be read easily by the average reader because the English translation is fraught with misprints and because the properties of the Mehler-Fock integral transform apparently are not widely known.

W. C. Orthwein, USA

3461. Florence, A. L., and Goodier, J. N., Thermal stresses due to disturbance of uniform heat flow by an insulated ovaloid hole, *ASME Trans.* **82** E *(J. Appl. Mech.)*, 4, 635–639, Dec. 1960.

Using steady-state thermoelastic equations of classical elasticity the stresses and displacements due to uniform heat flow in a plate disturbed by an insulated hole of ovaloid form are evaluated analytically, with the help of complex-function theory. Elliptical and circular holes are included as special cases.

A. E. Green, England

3462. Wilde, P., A thermoelastic problem for an orthotropic rectangular plate (in Polish), *Rozprawy Inz.* **7**, 4, 559–569, 1959.

To find the static thermal stresses in an orthotropic rectangular plate the method of finite Fourier transformation is used. The assumptions are those of classical thermoelasticity. The material and thermal constants are assumed to be independent of the temperature. The edge temperature is a given function. The heat is free to flow across the surface of the plate. The solution leads to an infinite system of algebraic equations.

It is shown that the case under consideration is dominated by that of intense heat absorption from the surface of the plate. In the case of weak heat exchange between the surface of the plate and the ambient medium infinite systems of equations are obtained, analogous to the corresponding equations for the clamped plate acted on by a uniform load.

A numerical example is given for a square isotropic plate in the particular case where the temperature of the edges and the ambient medium is constant. J. Ignaczak, Poland

3463. Piechocki, W., Axisymmetric dynamic problem of thermoelasticity for a solid sphere (in English), *Arch. Mech. Stos.* **12**, 4, 553–561, 1960.

The problem of propagation of elastic waves in a spherical body is solved. The waves are produced by a harmonically varying axially symmetric temperature field for zero thermal and stress surface conditions. After determining the temperature field in the infinite space expressed in the form of an infinite series of Bessel and Legendre functions the author superposes on it another thermal field, thus satisfying the zero thermal conditions on the surface. Next, the method of potentials is used to solve the thermoelastic problem for the infinite space thus obtaining the displacement in the form of a sum of longitudinal and transverse waves expressed in the form of combinations of cylindrical and spherical functions. Finding the stresses on the spherical surface, such as are given by solving the thermoelastic problem for the infinite space, author solves the thermal problem for a spherical body with a given surface load.

Of these two solutions the sought for solution for zero stress and thermal conditions is constructed.

The paper is original and constitutes a solution of one of the fundamental problems of the dynamical theory of thermal elasticity. J. Kacprzynski, Poland

3464. Piechocki, W., A quasi-steady-state thermoelastic problem of a circular disc (in Polish), *Rozprawy Inz.* **8**, 1, 95–100, 1960.

The problem of thermal stress in a circular plate produced by a time-variable temperature field is discussed. It is assumed that the plate is isotropic and homogeneous material and thermal constants being independent of the temperature and that the time-variability of the temperature is slow, so that the inertia terms in the equations of the theory of elasticity may be rejected. The temperature, which satisfies homogeneous initial and boundary conditions, is due to heat sources located inside the plate of which both surfaces are insulated. Two cases of elastic boundary conditions are considered: with the edge free from stress, and clamped. The solution is obtained in the form of quasi-static series.

The method of classical thermoelasticity is used. Thus the solution is assumed in the form of a sum of two functions of which one is a potential in the infinite plate due to a charge distributed according to the temperature function and the other constitutes the solution of the residual problem and is chosen in such a way that the stress or kinematic boundary conditions are satisfied.

J. Ignaczak, Poland

3465. Matczynski, M., Axially symmetric distribution of thermal stresses generated by periodic sources in the neighbourhood of a long hole in an infinite body (in English), *Bull. Acad. Polonaise Sci.* **8**, 8, 423–427, 1960.

Axially symmetric problem of stresses due to a circular ring heat source, varying harmonically with time, surrounding a long hole in an infinite body is solved, results being expressed as infinite integrals. There are no numerical illustrations of the theory. A. E. Green, England

3466. Uzdalov, A. I., Elastic equilibrium of bars having cylindrical anisotropy and subject to loads uniformly distributed along the length (in Russian), *Inzbener. Sbornik, Akad. Nauk SSSR* **26**, 148–160, 1958.

3467. Kuznetsov, A. I., Torsion of nonhomogeneous plastic shafts (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 11, 110–113, 1958.

Viscoelasticity

(See also Revs. 3482, 3486, 3603, 3641)

3468. Hilton, H. H., The divergence of supersonic linear viscoelastic lifting surfaces including chordwise bending, *J. Aerospace Sci.* **27,** 12, 926–934, Dec. 1960.

Author uses the general linear viscoelastic stress-strain relationships to obtain an elastic-viscoelastic analogy for creep deformations. An example is given for the case of torsional divergence. B. E. Gatewood, USA

3469. Aggarwala, B. D., Thermal stresses in spherical shells of viscoelastic materials (in English), *ZAMM* **40,** 10/11, 482–488, Oct./Nov. 1960.

Author obtains general solution for point symmetric thermal stresses in a hollow sphere of a general linear viscoelastic material whose material properties vary with temperature. The bulk modulus, however, is assumed to be temperature-independent, which appears to be a severe limitation on the generality of the results.

Solution is used to determine residual stresses in a Maxwell material having temperature-independent elastic properties and a viscosity which vanishes above a critical temperature and is infinite below this temperature. Problem considered is one in which shell cools from a particular temperature distribution which is everywhere above the critical temperature.

P. Seide, USA

3470. Hansen, T. C., Creep and stress relaxation of concrete (in English), Swedish Cem. Conc. Res. Inst. no. 31, 112 pp., 1960.

This is one of the most comprehensive papers on subject to date. Full but careful use is made of results of previous investigations. Each conclusion argued is soundly backed by experimental evidence. After showing that creep is a viscoelastic rather than a plastic behaviour, author develops a detailed examination of the microstructure of cement paste as a relationship between strength and Young's modulus of concrete. A large number of values from various investigations prove his relationship, showing that both properties are function of gel density.

The most important chapter develops the equation of specific creep as the sum of expressions for delayed elasticity and viscosity. Again good agreement exists with the results of numerous authorities. Specific creep is a function of time, of properties of constituents and of the combined proportions, but coefficients given by author make determination possible by design engineer as long as concrete is water-stored.

Author shows that effects of revibration and deformational properties of normal aggregates on creep are negligible, while temperature and water permeability of aggregates are important. Comprehensive discussion of effects of drying upon creep are given showing that large creep of drying concrete is not due to expulsion of water from cement gel under external load and revealing many other previously unpublished facts of behavior.

Work ends with interesting chapter on plastic deformation at high overload, as opposed to viscoelastic behavior known as creep, describing the breakdown of gel structure leading to failure and stress relaxation functions for concrete of great importance for prestressed concrete structures.

This report is strongly recommended to all engineers concerned with concrete structures. G. Little, England

3471. Bernett, E. C., Tensile and short-time creep properties of N-155 alloy sheet, *ASME Trans.* **82** B (*J. Engng. Industry*), 4, 283–302, Nov. 1960.

The special test equipment and procedures developed for the evaluation of ultrashort-time elevated-temperature mechanical properties of materials are described. The tensile and high-stress creep data obtained for Haynes N-155 alloy sheet are reported. At rapid strain rates, the high-temperature tensile strengths were up to 300 per cent higher than those obtained at conventional testing speeds. At high temperatures and high stress levels, however, creep rates were shown to be extremely rapid and, in most cases, the creep strength became a critical factor. The application of rapid-strain-rate tensile data and high-stress creep data in short-life designs is discussed. From author's summary

3472. Rigby, B. J., Power law for creep, *Brit. J. Appl. Phys.* **11,** 7, 281–283, July 1960.

A model is discussed which gives rise to the widely used power law for creep under constant load, namely, $dl/dt = \Omega t^{-n}$, where l is the strain, t the time, Ω a function dependent on temperature and load and n an exponent which may have any value between 0 and 1. In this model, the exponent n is interpreted as a function of the number of "flow units" which must be activated simultaneously before flow can take place.

From author's summary

3473. Gemma, A. E., The creep deformation of symmetrically loaded circular cylindrical shells, *J. Aerospace Sci.* **27,** 12, 953–954 (Readers' Forum), Dec. 1960.

3474. Rabotnov, Iu. N., and Robinovich, V. P., On the strength of disks in the presence of creep (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 4, 93–100, July/Aug. 1959.

Plasticity

(See also Revs. 3536, 3540, 3544, 3549, 3605, 3617)

3475. Hodge, P. G., Jr., Plastic analysis of circular conical shells, *ASME Trans.* **82** E (*J. Appl. Mech.*), 4, 696–700, Dec. 1960.

A right circular conical shell is subjected to axial load. The material is assumed to be rigid perfectly plastic. Hexagonal yield contours are adopted on the planes of direct forces and bending moments, without interaction between the two groups of variables. The problem is completely solved for moderately flat cones, with load acting on a central punch. The concentrated collapse load $2\pi M_0 \cos^2\alpha$ is found (M_0 yield bending moment per unit length, α edge angle). It applies independently of support and yield conditions and holds, as a lower bound, for general rotation symmetric shells. P. Cicala, Italy

3476. Rozenblium, V. I., Plasticity conditions for thin shells, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24,** 2, 520–524, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Author uses extremum principles for three-dimensional rigid-plastic materials to deduce simple approximate yield conditions for thin shells, the thickness being assumed small compared to a characteristic radius of curvature. Results are correlated with similar results already in the literature.

J. L. Ericksen, USA

3477. Lerner, S., and Prager, W., On the flexure of plastic plates, *ASME Trans.* **82** E (*J. Appl. Mech.*), 2, 353–354 (Brief Notes), June 1960.

Paper presents a simple test to check the fundamental theory of bending of rigid perfectly plastic plates described in *J. Mechanics and Physics of Solids* **2,** 1–13, 1952.

C. B. Matthews, USA

3478. Yoshimura, Y., Theory of plasticity for small and finite deformations based on legitimate concept of strain, Aero. Res. Inst., Tokyo University, Rep. 348-161-219, Sept. 1959.

The proposed definition of strain is intended to serve for problems involving the Bauschinger effect and the development of anisotropy, in which strain history is important. The author overlooks much progress with conventional definitions of strain increment, as for example, Hill, R., AMR 4(1951), Rev. 2471. His proposed treatment does not seem to be applicable to as wide a variety of histories, for example alternating tension and compression, as does that of Ilyushin, AMR 9(1956), Rev. 2854.

F. A. McClintock, USA

3479. Colonnetti, G., Interpretation of elastic-plastic phenomena in terms of the linear theory of heredity (in Italian), *Atti Accad. Naz. Lincei, R. C. Cl. Sci. Fis. Mat. Nat.* **27,** 1/2, 14-19, July/Aug. 1959.

Elastic-plastic bending of a prismatic rod is considered, supposing that the total strain is a function of the distance from the neutral axis. Author also assumes that the plastic strain rate is a function (a series development) of the total strain. No reference to a stress-strain law is made. For the reviewer it is difficult to understand in which particular cases these suppositions can be made.

N. E. Cristescu, Roumania

3480. Storchi, E., Problems in plasticity (in Italian), *R. C. Semin. Mat. Fis.* **29,** 103-152, 1959.

This is a review of the author's results in research work regarding statically determinate problems of plasticity, with particular reference to the problems of plane strain and plain stress. It is also shown that the statically determinate problems of plasticity can always be linearized.

From author's summary by G. W. Housner, USA

3481. Dobrovol'skii, V. L., The problem of plane strain of a perfectly plastic body in terms of complex variables, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24,** 2, 525-529, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N.Y.)

For plane strain of an ideal plastic solid, author uses complex variables to obtain a general solution of the governing equations in terms of arbitrary functions. He indicates that simple choices of these produce several simple known solutions, and briefly discusses matching elastic and plastic solutions.

J. L. Ericksen, USA

3482. Bayce, A. E., Ludemann, W. D., Shepard, L. A., and Dorn, J. E., Effect of stress on the creep of aluminum in the dislocation climb range, *Trans. Amer. Soc. Metals* **52,** 451-468, 1960.

The effect of stress on the creep rate in the dislocation climb region was investigated by increasing and decreasing the stress abruptly during the course of primary creep of high-purity aluminum. These investigations reveal that a simple functional relationship between creep rate and stress does not exist; the effect of stress on the creep rate depended on the substructure as well as the stress. In general the creep of aluminum under conditions of changes in stress can be resolved qualitatively in terms of dislocation climb models for creep.

From authors' summary by G. V. Smith, USA

Rods, Beams and Strings

(See also Revs. 3411, 3457, 3494, 3508, 3509, 3512, 3513, 3515, 3612)

3483. Michalos, J., and Birnstiel, C., Movements of a cable due to changes in loading, *Proc. Amer. Soc. Civ. Engrs.* **86,** ST 12 *(J. Struct. Div.)*, 23-38, Dec. 1960.

A numerical method is presented for the determination of displacements along a suspended cable resulting from change in load. The effect of elastic deformations is included. All computations in the numerical examples were made with the aid of a desk calculator. The procedure, however, is particularly suitable for programming for an electronic digital computer.

From authors' summary

3484. Mertens, J. J., The torque in highly twisted nylon 6 monofilaments, *J. Textile Inst., Trans.* **50,** 1, 70-82, Jan. 1959.

Theoretical considerations have lead to the following formula for the torque M in highly twisted monofilaments with a circular cross section:

$$M = 2\pi d^3 \int_0^{\frac{1}{2}} \tau\,[\rho/d] \cdot (\rho/d)^2 \cdot d\,(\rho/d),$$

where d = the filament diameter;

ρ/d = the relative radial distance from the axis;

$\tau[\rho/d]$ = the shear stress at ρ/d from the axis.

With this formula it appears to be possible to compare the torques in highly twisted filaments which have been subjected to different treatments before twisting, in such a way that the influence of the resulting differences in diameter can be separated from the effects of the differences in molecular structure.

The influence of the differences in diameter can be eliminated by changing over from the observed torque M to the "reduced torque" M^* ($= M/d^3$, d = filament diameter), i.e., the torque which would exist in the filament under geometrically similar conditions if this filament had a diameter of unit length.

Experiments were made on nylon 6 monofilaments in order to investigate the effect of processes, such as drawing and heat-setting under various conditions of time, temperature and tension, on the "reduced torque" and its torsional relaxation.

The value of the reduced torque increases with the drawing of the monofilament. This applies to a smaller extent to the set filaments. In this case, a maximum reduced torque occurred in filaments set under rather different conditions as regards time and tension, provided that the filaments have a birefringence of at least 0.054. The reduced torque of filaments increases as the setting temperature is raised.

The various filaments show only small differences in torsional relaxation.

From author's summary

3485. Sonntag, G., The half-plane composed of equal thickness layers with periodically distributed boundary loading (in German), *Forsch. Geb. Ing.-Wes.* **26,** 5, 133-140, 1960.

A semi-infinite elastic solid is built up in layers, like a stack of planks. Load on top plank is a sine wave (lengthwise) plus a uniform part. The two-dimensional problem is examined for effects of two kinds of frictional resistance between planks: (a) a constant coefficient of friction, (b) a frictional shear stress proportional to slip (displacement) between planks.

Uniform part of load is large enough to ensure no separation of planks. Effects of sine part die out with depth, less rapidly than for solid medium, more rapidly than with zero friction. Planks are treated as beams, and difficulties introduced by friction direction in (a) are dealt with by further Fourier approximation.

J. N. Goodier, USA

3486. Sackman, J. L., Steady creep bending of a nonhomogeneous beam, *J. Aerospace Sci.* **28,** 1, 11-14, 33, Jan. 1961.

Referring to earlier work by Freudenthal and Bleich, author goes beyond the simple Bernoulli-Euler theory of bending to examine the case of a beam with "hard" or "stiff" face on one side and "soft" face on the other. The difference in behavior when

load is applied to one face or the other is noted. Velocity of flow of various parts of the beam is examined, leading to an analysis of creep behavior. A. G. H. Dietz, USA

3487. Opladen, K., Analysis of beams on elastic foundations in the case of variable foundation modulus and variable bending stiffness (in German), *Bautechnik* **37**, 11, 428–436, Nov. 1960.

Previous works on the title subject covered the case of beams of constant bending stiffness on elastic foundations with variable foundation moduli. This article extends analysis to the case of variable bending stiffness by using finite differences equations to replace the differential equations. This allows for all the variable values, i.e. foundation modulus, bending stiffness and distributed load, to be given numerically. The beam is subdivided into finite portions wherever there is discontinuity in any of these values or where a concentrated load is applied. The case of infinitely stiff structures (or portions thereof) is also dealt with. An example fully illustrating the method is worked out numerically.

J. Solvey, Australia

3488. Raymondi, C., Additions to the study of beams on elastic foundations (in Italian), *Atti Ist. Sci. Costr. Univ. Pisa* no. 65, 21 pp., 1959.

This is a complement to a former note on the same item, issued in the same periodical, no. 60, 1958 [AMR **13**(1960), Rev. 3317] in which it was shown that the problem of the beam on elastic foundation could be represented by a singular integrodifferential equation of the third order. The present paper, highly mathematical in nature, concentrates on the problem of the derivability of the soil reaction $q(x)$ in the case of a bilateral connection between beam and soil, and shows in which class of functions the solution of the problem normally belongs. In particular, the author discusses the shape of the function $q(x)$ in the vicinity of sections where concentrated couples are applied to the beam. The importance of the eigenvalues and eigenfunctions of the problem is emphasized, in view of a future discussion of the modified problem which arises when contact between beam and foundation is unilateral.

C. E. Massonnet, Belgium

Plates, Shells and Membranes

(See also Revs. 3413, 3414, 3475, 3476, 3477, 3481, 3511, 3563)

3489. Melosh, R. J., A stiffness matrix for the analysis of thin plates in bending, *J. Aerospace Sci.* **28**, 1, 34–42, 64, Jan. 1961.

Airplane wings can be analyzed as thin plates of variable thickness. Instead of using the Rayleigh-Ritz method, the direct solution of the differential equation is accomplished by finite difference method. The stiffness matrix for thin plates subject to bending and lateral forces has been determined assuming the displacement along the edges of the panel as third-order polynominals. The stiffness matrix exhibits excellent convergence characteristics.

Reviewer believes that the method shown in the paper can be used for more complex problems, such as the vibration of folded plates. A numerical example shows the practical application of the method. R. Szilard, USA

3490. Salvadori, M. G., and Reggini, H. C., Simply supported corner plate, *Proc. Amer. Soc. Civ. Engrs.* **86**, ST 11 (*J. Struct. Div.*), 141–154, Nov. 1960.

A corner plate, simply supported on two parallel boundaries, each composed of two semi-infinite straight lines meeting at right angles, is uniformly loaded. Bending and twisting moments and shears and boundary reactions in the plate are determined by finite-difference integration of the corresponding boundary-value problem. The penetration into the side strips of the disturbance represented by the corner is shown to be practically negligible at a distance from the inner corner of the order of the width of the side strips. From authors' summary

3491. Meyerhof, G. G., Bearing capacity of floating ice sheets, *Proc. Amer. Soc. Civ. Engrs.* **86**, EM 5 (*J. Engng. Mech. Div.*), 113–145, Oct. 1960.

The collapse of floating ice sheets under load is estimated on the basis of a rigid-plastic plate on an elastic foundation for various loading and boundary conditions. The results are compared with field observations in the operation of ice roads and floating airfields and some small-scale loading tests.

From author's summary

3492. Czerny, F., Hydrostatically loaded plate of arbitrary shape with one free edge in the plane of the water surface (in German), *Bauingenieur* **35**, 8, 302–309, Aug. 1960.

Paper presents method for arriving at approximate solution of title problem. Author first develops series solution for submerged rectangular plate in the vertical plane with a free edge at the surface of the water and clamped at the other three sides. It is indicated that this solution has been tabulated and is now in the process of being published.

In the case of a plate having a submerged boundary of arbitrary shape, a linear combination of additional functions is superimposed such that the boundary conditions are satisfied at a specified number of discrete points on the boundary. Each of the superimposed functions is taken as the solution of the homogeneous plate equation in polar coordinates and satisfies the conditions at the free upper edge of the plate. The number of such functions must, of course, be equal to the total number of conditions which are to be satisfied at the discrete boundary points. To improve accuracy, author elects to enforce conditions $w_s = 0$ along the boundary in addition to $w = w_n = 0$ at the boundary rather than increasing the number of points at which the latter two conditions are to be satisfied. The boundary conditions at the discrete points lead to a set of simultaneous linear algebraic equations in the weights or coefficients of the superimposed functions.

The method is illustrated by application to a semicircular plate and to an isoceles triangle. J. E. Goldberg, USA

3493. Todjbakhsh, I., and Saibel, E., On the elastic deflections of plates (in English), *ZAMM* **40**, 5/6, 259–268, May/June 1960.

Similarly to the paper of G. Herrmann [AMR **9**(1956), Rev. 3859] the author starts from the equations of strain components for the case of small elongations and shears but moderately large rotations. The assumptions that the normals to the middle plane of the plate remain normal after the deformation, the displacements vary linearly in the z-direction, and the validity of the Hooke law, enable the author to express the shear stresses and the moments by a displacement function φ and the deflection w; the stresses σ_{xz}, σ_{yz} normal to the plane of the plate vanish. However, in the equations of motion the authors preserve the expressions containing the rotations and σ_{xz}, σ_{yz}, assuming that they are even functions in z. Thus the problem is reduced to a system of five partial differential equations with the unknown functions ψ, w and the force components in the plane of the plate. Introducing nondimensional quantities authors apply a perturbation scheme with the small parameter ε; preserving the leading terms of the expansion he arrives at the equations of motion, the statical part of which constitutes the well-known Karman equations. The authors' equations however are not Karman's equations extended by mere inclusion of the inertia term. They are more complicated. Next the equation is given resulting from collecting the coefficients of ε to the first power.

Finally, a plate loaded symmetrically has been examined, and as a particular case a clamped plate uniformly loaded.

W. Urbanowski, Poland

3494. Raasch, J., The stresses in a circular ring plate bent by an antisymmetric force system applied along the inner edge (in German), *Ing.-Arch.* **29**, 6, 419–424, 1960.

Solution is obtained of a Lagrangian title plate loaded along the inner edge in such a manner that the transverse deflection of the plate may be written in the form

$$w = (Ar^3 + Br + Cr^{-1} + Dr\ln r)\cos\varphi$$

The four constants of integration are calculated for four different combinations of boundary conditions. Stress distribution variation is illustrated in graphs. The effect of the relative size of the central hole is also considered.

S. J. Medwadowski, USA

3495. Elpat'evskii, A. N., Analysis of cantilever plates by the variational method of V. Z. Vlasov (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **28**, 212–219, 1960.

Using the potential energy method, author has considered thin, elastic, cantilever plates of an arbitrary shape. As a particular case the triangular plate is taken. Z. Olesiak, Poland

3496. Matildi, P., Equation solving the problem of the slice-plate and corresponding duality considerations (in Italian), *Atti Ist. Sci. Costr. Univ. Pisa* no. 64, 14 pp., 1959.

The paper is divided in two parts. In the first, it is shown that the problems of the elastic plate subjected to transverse forces and that of the plane elastic slice, acted upon by forces in its plane, may be solved simultaneously by means of a unique biharmonic function in the complex plane. The interest of this solution lies in the fact that it seems possible to extend it to the case of shallow shells.

In the second part, detailed dual relations between the two cited problems are developed and, in particular, the moment tensor in the bent plate is shown to derive from a stress vector (U, V), which plays the same role as the displacement vector (u, v) in the case of the plane slice. C. E. Massonnet, Belgium

3497. Ishkova, A. G., Bending of a strip and a circular plate lying on the elastic semi-space (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **28**, 171–181, 1960.

An infinite strip and a circular plate lying on the elastic semi-space are bent by shearing forces and forces acting in the plate surface. The problem is reduced to solving the infinite system of equations with the infinite number of unknown coefficients. For some special cases the values of contact pressure are given in tables. Z. Olesiak, Poland

3498. Bufler, H., Stresses in two elastic half planes consisting of connected bodies (in German), *Ing.-Arch.* **29**, 4, 233–249, Aug. 1960.

In a previous paper [*ZAMM* p. 218, 1959] author submitted and solved integral equations derived from the boundary values for the pressure and shear stresses of two different elastic half disks of the same thickness. In this article he establishes stresses for both disks by using the complex variable method of G. V. Kolosov and N. I. Muskhelishvili [See "Some basic problems of the mathematical theory of elasticity," 4th ed., Moscow, 1954]. For the lower disk a stress function is given, an integral equation is set up from the boundary values; same for the upper disk, and both functions equated $\phi_1(x) = -\phi_2(x)$. Five cases are discussed: (1) Pure compression or tension; (2) shear without torsion; (3) pure shear; (4) pure torsion; and (5) heat stresses. To get an idea of the stress distribution, stresses along the joint of both disks and extreme values of symmetrical points are plotted. Both half disks are of the same material, same thickness, one half being considered rigid. M. Maletz, USA

Book—3499. Flugge, W., Stresses in shells, Berlin, Springer-Verlag, 1960, xi + 499 pp. DM 58.80.

The book is divided into seven chapters, the first six treating by linear theory the problem of stresses and deformations in shells of various shapes. The last chapter pertains to buckling of shells. In the first chapter fundamental concepts and definitions are discussed and relations obtained for stress and moment resultants in arbitrary directions in a general shell. The generalization extends as far as oblique coordinates but does not include generalized curvilinear coordinates. The second chapter treats the problem of membrane stresses in shells of revolution. After a brief development of fundamental theory various problems such as ellipsoidal shells, cylindrical shells with a reinforced cutout, ogival shells, two intersecting spheres, toroidal shells, supported spherical tanks, and drop-shaped tanks of constant strength are analyzed in detail for stresses amd deformations. In all of these problems the loadings are assumed to be axisymmetric. Toward the end of the chapter more general equations for membrane shells of revolution wherein the loads are non-axisymmetric are developed. The cases of wind forces acting on a spherical dome, antisymmetric forces and movements applied at the ends of a diameter of a spherical shell, and nonuniform edge loads on a hemispherical shell are investigated in detail. Also, the problem of a tangential load acting at an arbitrary point on a complete spherical shell is solved.

The third chapter treats the problem of membrane stresses in cylindrical shells. Again, there is a brief exposition of basic theory and then a variety of boundary-value problems are investigated. The problems of a cantilever shell subject to variable lateral load along its length and the problem of circular and elliptical cylinders filled with liquid are treated. Considerable attention is devoted to the problem of the barrel-type roof shell. The chapter closes with a detailed investigation of shells in the form of folded elements, i.e., each element is in a form of a long but narrow flat plate. The fourth chapter treats the problem of membrane stresses in shells of arbitrary shape. Shells in the form of a paraboloid of revolution, an elliptic paraboloid, and in the form of a hyperbolic paraboloid are treated in detail both by analytical methods as well as finite difference techniques. The fifth chapter treats the important problem of bending of circular cylindrical shells. After a derivation of the governing equations in the form originally proposed by the author some years ago, numerous boundary-value problems are discussed. Problems of edge loadings of cylindrical shells, roof shells in the form of a barrel-arch, cylindrical shells partially filled with liquid, cylindrical tanks of either constant or variable thickness filled with liquid, and the ring-reinforced shell subject to uniform radial pressure are treated in detail. There is also an exposition of elastic behavior of anisotropic shells and applications of this theory to shells reinforced with rings and stringers. The chapter closes with an exposition of bending theory of shells in the form of folded structures. The sixth chapter treats the general problem of bending stresses in shells of revolution. The governing differential equations are derived and solved for a variety of axially symmetric loadings. The important technique of asymptotic solutions for such thin shells is presented in considerable detail. This is one of the significant aspects of the treatment offered in this chapter. The general equations are specialized for the cases of shells of constant and variable wall thickness and various approximate forms of solution are discussed for each of these cases. Special cases such as the constant wall thickness conical shell and variable wall thickness conical shell as well as the constant thickness spherical shell are investigated in detail.

The seventh chapter investigates buckling of thin elastic shells. The approach is based largely upon classical small-deformation

theory with major emphasis upon the cylindrical shell with a slight mention of a buckling of a spherical shell. Only a small discussion is offered on nonlinear theories of buckling of such thin shells. The book concludes with a short appendix discussing forces and deformations in circular rings.

The bibliography at the end of the book presents a very complete listing of significant works in this area. In summary, the book presents a significant contribution to the area of thin elastic shells since it offers the most modern treatment in the English language of both basic theory and applications in this important field.

W. A. Nash, USA

3500. Cheng, D. H., and Weil, N. A., The junction problem of solid-slotted cylindrical shells, *ASME Trans.* **82** E (*J. Appl. Mech.*), 2, 343–349, June 1960.

One method of supporting vertical closed-end pressure vessels (towers) is to set them on a short cylindrical shell referred to as a skirt. Generally, the junction between the tower and skirt is made by a continuous fillet weld. Since the stresses at this junction are very high ($>10^4$ psi) cyclic conditions may rapidly induce fatigue failures. Effective reduction of these junction stresses may be achieved through lowering of thermal gradients by rearrangement of insulation and by slotting the skirt and thereby reducing its stiffness. The paper presents solutions of the slotted skirt attachment problem. The solutions, though tedious, yield readily to high-speed digital computer methods.

C. B. Matthews, USA

3501. Wilson, B., Asymmetrical bending of conical shells, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 3 (*J. Engng. Mech. Div.*), 119–139, June 1960.

After justifying the use of the consistent equations of Gol'denweizer with the stress-strain relations of Novozhilov, author specializes them for the case of circular conical shells and solves them by means of separation of the variables. The ordinary equations in the longitudinal variable are solved by a Frobenius series, as suggested by Hoff.

The conical shells considered are simply supported along two generators and may have any conditions satisfied on the transverse sections of the truncated cone.

The series solutions for the stresses converge very slowly and could not be used for actual stress evaluation without the use of an electronic computer. Author has programmed the solution on an IBM 650 and presents in tabular form and in graphs the stresses for two truncated cones under radial internal pressure.

M. G. Salvadori, USA

3502. Chernina, V. S., State of stress of a toroidal shell of medium thickness (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 3, 96–104, May/June 1959.

Toroidal shells of medium thickness ($R/b = 3$–4) are treated on basis of Reissner's and Naghdi's variant of theory of shells taking into consideration the effect of shearing forces. For toroidal shells of medium thickness, differential equation for the case of a rotatory symmetric deformation is derived, consisting of two parts. The principal part of that equation represents the differential equation of deformation of a thin shell, additional terms being small in comparison to the principal part. Because of that a solution in the form of potential series in a small parameter is possible. Taking into account the exactitude of the assumptions basic to Reissner's theory, it is enough to take two first terms of the series only.

Results of a numerical example are presented. Diagrams of stress distribution allow a comparison with corresponding values obtained by means of the theory of thin shells.

Natalija Naerlovic, Yugoslavia

3503. Ganowicz, R., A plate strip having ribs on one side (in Polish), *Rozprawy Inz.* **8,** 2, 325–342, 1960.

The problem under consideration is that of a plate strip satisfying the thin plate assumptions and having ribs on one side. The ribs, which are identical and evenly spaced, are arranged in two mutually perpendicular directions. The rib spacing is small in relation to the width of the plate. One of the directions of the ribs is parallel to the axis of the strip. The ribs are symmetric and have no torsional rigidity. The solution of the problem is assumed in the form of a trigonometric series. As a result, functions are obtained which can be represented in a finite form. The problem is reduced to the solution of an ordinary differential equation of the eighth order for the displacement function. A particular problem (taken from model tests that were carried out) is solved.

Z. Olesiak, Poland

3504. Katzoff, S., The surface-tension method of visually inspecting honeycomb-core sandwich plates, *Nondestructive Testing* **18,** 2, 114–118, Mar./Apr. 1960.

When one face of a metal-honeycomb-core sandwich plate is heated or cooled relative to the other, heat transfer through the core causes the temperature on each face at the lines of contact with the core to be slightly different from that on the rest of the face. If a thin liquid film is applied to the face, the variation of surface tension with temperature causes the liquid to move from warmer to cooler areas and thus to develop a pattern corresponding to the temperature pattern on the face. Irregularities in the pattern identify the locations where the core is not adequately bonded to the face sheet. The pattern is easily observed when a fluorescent liquid is used and illumination is by means of ultraviolet light. Observation in ordinary light is also possible when a very deeply colored liquid is used. A method based on the use of a thermographic phosphor to observe the temperature pattern was found to be less sensitive than the surface-tension method. A sublimation method was found to be not only less sensitive but also far more troublesome.

From author's summary

3505. Laslo, N., Flat slabs without drop panels (in Roumanian), *Rev. Construct.* **11,** 3, 105–114, Mar. 1959.

Paper describes a building constructed with flat slabs without drop panels. Theoretical problems which appeared during the design of such slabs are discussed, the calculation of the shearing strength being emphasized. A series of tests carried out in the U.S.A. are expounded by analysis based on the Soviet ultimate strength method. Very good concordance is found between analytical and test results.

Conclusions are drawn and recommendations are made on the design and structural analysis of slabs working in shearing stress.

From author's summary

3506. Kurdin, N. S., Large deflections of a rectangular membrane, stiffened by an elastic rib (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 8, 117–119, Aug. 1958.

This paper discusses a nonlinear problem on rectangular membrane, stiffened by a single rib, using the energy method approach. A numerical example is utilized to study the influence of the rigidity of the rib (loaded in axial tension and bending), and of the dimensions of the membrane on its deformed state. Deflection coefficients, as functions of load and membrane propertions, are cited and compared with those due to Timoshenko and Foeppl.

Z. W. Dybczak, Canada

Buckling

(See also Revs. 3493, 3643)

Book—3507. Timoshenko, S. P., and Gere, J. M., Theory of elastic stability, 2nd ed.. New York, McGraw-Hill Book Co., Inc., 1961, xvi + 541 pp. $15.

Professor Stephen P. Timoshenko has written many books in the field of applied mechanics and these have played an important part in stimulating and improving American engineering education. The one which has had the greatest influence is the book entitled "Theory of elastic stability." From the time this work first appeared in an American edition in 1936 it has been the leading book on the subject of elastic stability and the principal source of information in the field to a generation of applied mechanicists as well as practical engineers. The special characteristics of books written by Professor Timoshenko include excellence of presentation, crystalline clarity and ease of introduction of subject to the reader. In addition, his books indicate mastery and deep knowledge of the material. This particular work adds to these other qualities the special merit of bringing together most of the original research work done in the field of elastic stability by Professor Timoshenko.

The energy method used by Rayleigh, the famous British physicist, to calculate approximately natural frequencies of vibrations of elastic systems inspired the young Timoshenko, an instructor at St. Petersburg Technical Institute, to develop a similar energy method for solving problems of elastic stability based on the comparison of the strain energies of the system in its initial and buckled shapes. Energy methods had already been used by George Bryant in the study of instability problems in elastic plates, but it was Stephen Timoshenko who systematically developed and applied an energy method to the study of almost all possible cases of elastic stability, from slender columns to arcs, from frames to thin-walled structures, from plates to shells, and made it the most powerful tool in the hands of applied mechanicists for solving problems of elastic stability.

The results of Timoshenko's early work in this field were published in 1913 in the French periodical *Annales des Ponts et Chaussées* under the title "Sur la Stabilité des Systèmes Elastiques." This classical paper made Timoshenko's name known among the scientists of western Europe.

The changes and additions in the new edition of this book can be summarized as follows: The new edition consists of eleven chapters, two new chapters (Chapter 3 on inelastic buckling of bars and Chapter 5 on torsional buckling) having been added to the original nine chapters of the 1936 edition. Chapter 2 (on elastic buckling of bars and frames) is enlarged to include buckling under the action of nonconservative forces, periodically varying forces and impact. Chapter 6 (on lateral buckling of beams) is extensively revised. In Chapter 9 (on buckling of thin plates) several new cases of buckling are considered, and tables for calculating critical stresses are added. In Chapter 11 (on buckling of shells) buckling of curved sheet panels, spherical shells, stiffened cylindrical shells and postbuckling behavior of compressed cylindrical shells are added. As usual in books by Professor Timoshenko, a complete up-to-date bibliography of published material and authors is presented in footnote form in the text and is a valuable reference to research workers.

The new edition of this classical book will be welcomed by applied mechanicists around the world. It adds to the impressive list of Stephen P. Timoshenko's contributions to engineering mechanics.

E. G. Volterra, USA

3508. Mikhailichenko, K. A., Stability of systems of pinned bars (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **26**, 252–269, 1958.

Author shows that approximate analysis of stability according to N. W. Kornoukhov ["Strength and stability of framed structures," 1949] must not be used when the critical load causes great deformations.

A. Werfel, Israel

3509. Seide, P., The effect of pressure on the bending characteristics of an actuator system, *ASME Trans.* **82** E (*J. Appl. Mech.*), 429–437, Sept. 1960.

W. Fluegge has shown theoretically that long simply supported cylinders with fixed end-separation may buckle under internal pressure. For stresses to remain elastic the length must be in excess of approximately 50 times radius. For more normal dimensions, bursting will occur before buckling. In case of bellows, however, buckling may occur even with small values of length-radius ratio.

Present paper employs small-deflection beam theory to analyze behavior of cantilever bellows subjected to internal or external pressure. Moveable end is clamped to rigid plate which is constrained by rigid arm to rotate about fixed pivot on (undeflected) longitudinal axis of the bellows. Such a constraint normally decreases volume of bellows when end is deflected a small distance, so external pressure decreases stiffness of cantilever; for this case theory and experiment are found to be in good agreement. Internal pressure tends to exaggerate curvature of the neutral axis of bellows and for sufficiently high internal pressure, bellows volume will be increased rather than decreased when end is deflected. Thus theory predicts that as internal pressure increases, stiffness of cantilever first increases, then decreases. Experimental data confirm increase but not decrease. Author attributes discrepancy to friction in bellows, which was of multi-ply construction.

S. B. Batdorf, USA

3510. Konig, H., The buckling load of a bar clamped at one end and subjected to a force whose direction varies (in German), *Stahlbau* **29**, 5, 150–154, May 1960.

Title problem is discussed by examining static and kinetic domains of solutions of the differential equation governing damped vibration of a homogeneous prismatic rod subjected to constant longitudinal thrust. Instability may occur for thrusts that are in some cases less and in others greater than the Euler load.

K. S. Pister, USA

3511. Peterson, J. P., and Card, M. F., Investigation of the buckling strength of corrugated webs in shear, NASA TN D-424, 29 pp., June 1960.

Design charts are presented from which the buckling strength of corrugated shear webs can be determined. The charts are applicable to webs with supported edges in which the edge rotations of the web along lines of support may range from unrestrained (simply supported) edges to completely restrained (clamped) edges. In addition, the results of shear tests on seven beams with corrugated webs are presented and discussed.

From authors' summary by O. Csellar, Hungary

3512. Adamov, V. N., and Kazazaev, V. N., Stability and deformation analysis of frames (in Russian), *Inzbener. Sbornik Akad. Nauk SSSR* **26**, 236–251, 1958.

Paper contains some recommendations for the practical analysis of frames. The criteria are whether or not, in analyzing the strength of a frame, its deformation needs be considered and whether its stability under given load has to be checked or not.

Instead of analyzing the stability of frames in the classical way, authors recommend to analyze their strength on the assumption that their members contain some inevitable imperfectness. The bars termed "straight" have to be considered as crooked in affinity with the deflection curves, which would appear after buckling of the frame under corresponding forces acting upon the joints only.

All these recommendations are based on the analysis of a few simple examples only. Their comprehensive check appears, therefore, to be indicated.

A. Werfel, Israel

Vibrations of Solids

(See also Revs. 3413, 3489, 3510, 3524, 3528, 3618, 3629)

3513. Caughey, T. K., Random excitation of a loaded nonlinear string, *ASME Trans.* **82** E (*J. Appl. Mech.*), 3, 575–578, Sept. 1960.

The mean square deflection of a taut massless elastic string carrying N equally spaced masses subject to N uncorrelated white noise forces is calculated. The nonlinearity due to the increase in string tension which results from the deflection is approximately accounted for by the method of equivalent linearization. The effect of the nonlinearity is to decrease the mean squared deflection in comparison to the linear case. S. H. Crandall, USA

3514. Caughey, T. K., Forced oscillations of a semi-infinite rod exhibiting weak bilinear hysteresis, *ASME Trans.* **82** E (*J. Appl. Mech.*), 4, 644–648, Dec. 1960.

This paper considers a semi-infinite rod having bilinear hysteresis, with sinusoidal excitation at the free end, $x = 0$. First-order analysis gives the variation of strain amplitude and phase along the length of the rod. Results are compared with those for a viscoelastic solid. J. D. Robson, Scotland

3515. Solecki, R., Free vibrations of rectangular cross-section beam with parabolic variable height (in Polish), *Inzyn. Budown.* **15**, 8, 278–284, Aug. 1958.

Author takes in consideration free transversal vibrations of a bar of constant width and variable height $b(x)$, according to equation $b(x) = b_0 \cdot (1 + \beta\, x/l)$. The influence of rotational inertia and shearing are neglected. The bar axis is taken as rectilinear and the mass distribution is symmetrical to this axis. Such a postulate has many advantages over the formulation by E. T. Cranch and A. A. Adler [*J. Appl. Mech.* **23**, 1, p. 103, 1956]:

1. The cross-section variation has a practical value, the height b of the bar is finite at the ends;

2. We may derive the vibration frequency as a function of β, i.e. of the shape of the bar;

3. The problem is easy to solve, because the corresponding differential equation has no singular points in the interval of the independent varable x;

4. The obtained solutions are not a good approximation when the upper or lower surface is plain. Then the axis of the bar is not straight, but if the value of b_{max}/l is not too large, we may apply the approximate relation $EI(x) \cdot y'' = M(x)$.

Author introduces a nondimensional factor $\varphi(x) = 1 + \beta\, x/l$ for the cross sections $A(x)$ and the corresponding moment of inertia $I(x)$:

$$A(x) = b \cdot b(x) = A_0 \cdot \varphi^2;$$

$$I(x) = \tfrac{1}{12} A_0 b_0^2 \varphi^4 = I_0 \varphi^4,$$

and obtains the equation of the problem as an Cauchy-Euler equation, which easily reduces to an equation with constant coefficients. Thus the general solution with four constants for the amplitude may be obtained. After this, author deduces frequency equations for 4 types of edge conditions: (1) the bar with clamped ends, (2) supported ends, (3) a cantilever bar, (4) one end clamped and the other supported. At the end, the computation of the fundamental frequencies of bars with clamped and supported ends has been shown in full extent, with table and diagrams.

J. S. Naleszkiewicz, Poland

3516. Nowacki, W., The problems of combined bending and compression, stability and vibration of a plate strip and a rectangular plate (in Polish), Ksiega Jubileuszowa dla Uczczenia Zaslug Naukowych Prof. Dra Witolda Wierzbickiego, Warszawa, Panstwowe Wydawnictwo Naukowe, 1959; 158–184.

Author begins with the solution of an auxiliary problem. This is the problem of deflection of a plate strip and a rectangular plate clamped along the edges and acted on by forces lying in its plane and by normal forces constant or variable with time. The simply supported strip loaded with additional unknown forces evenly spaced or continuously distributed along the strip is assumed to constitute the basic system. The solution is obtained in the form of trigonometric series.

Next a number of problems of combined bending and compression, stability and free and forced vibration are solved for a plate strip simply supported or clamped along the edges and for a rectangular plate clamped along the edges. In the last case the problem is reduced to that of a Fredholm integral equation of the first kind. This leads to an infinite system of equations of better convergence than with other methods. Thus, for instance, it suffices to take a determinant of lower order than in the works of other authors to obtain results of the same accuracy.

The method presented can easily be generalized to the case of a plate strip or a rectangular plate compressed in two directions.

J. Mutermilch, Poland

3517. Soloviev, V. V., On vibration of the air flow in the pipe bundles of a steam generating unit (in Russian), *Teploenergetika* no. 7, 32–34, July 1960.

Author considers the reasons for vibration which arises due to instability of the air and gas flow round the bundles of pipes and the methods for their elimination.

From author's summary

Book—3518. Gurov, A. F., Bending vibrations of members and the assembly of aircraft gas turbine engines [Izgibnye kolebaniya detalei i uzlov aviatsionnykh gazoturbinnykh dvigatelei], Moskva, Gosudarstvennoe Izdatel'stvo Oboronnoi Promyshlennosti, 1959, 359 pp. 17 r 90 k.

The high-efficiency jet engine requires a design philosophy of close attention to details in all respects. It has been observed in the past that the vibrating motion is one of the most fundamental considerations facing a designer of a new aircraft for transonic and supersonic flight.

In general, any jet engine consists of external housing and vibrating parts. These vibrating parts are attached to the external housing with an elastic mechanical system and consist of a compressor and a turbine which drives the compressor with an angular velocity ω, varying during operation.

The compressor rotor consists of "discs" of different diameters which are mechanically linked.

During operation, the complete system, i.e., rotor and stator, is subjected to vibration. The cause of these vibrations can be an uneven mass distribution on the rotor, lack of axial symmetry of the spring constants, or some aerodynamic effect generated by the flow during operation.

Gurov's book represents an excellent contribution in this direction. Chapter I of the book's two chapters contains formulation of integral equations for the case of free vibrations. Gyro-effects and rotatory inertia effects are taken into account. Chapter II represents forcing vibration of two- and three-bearing machine.

The solution for dynamical response of the machine during operation is presented in the form of a set of functions which are tabulated.

It is worthwhile to note that a general method concerning the vibration of three-bearing jet engines has been developed independently by the reviewer of this book and Mr. J. K. Sevcik, in the summer of 1959, at General Electric Company in Cincinnati.

The book is excellently written from a mathematical point of view, so that any engineer should be able to follow its development. The book is useful for everyone working in the field of vi-

bration of turbines or jet-engines. In the opinion of this reviewer, such a book well merits translation into English.

M. M. Stanisic, USA

3519. Caughey, T. K., Random excitation of a system with bilinear hysteresis, *ASME Trans.* **82** E (*J. Appl. Mech.*), 4, 649–652, Dec. 1960.

This paper treats a single-degree-of-freedom system with viscous damping and bilinear hysteresis, subjected to white noise excitation, by deriving equivalent damping and spring coefficients. Curves are given from which these quantities, and so the mean-square displacement, can be obtained, subject to certain assumptions. For large inputs the mean-square displacement is increased by the presence of hysteresis.

J. D. Robson, Scotland

3520. Arlaratnam, S. T., Random vibrations of nonlinear suspensions, *J. Mech. Engng. Sci.* **2**, 3, 195–201, Sept. 1960.

Physicists have known for some time that (n-degree-of-freedom) system response is a ($2n$-dimensional) Markov process if the system input is gaussian white noise (derivable from a real gaussian process with independent increments or a Wiener process), and that the output statistics may be obtained from the first conditional density function which satisfies a Fokker-Planck equation. As a result, the literature on Markov processes and the Fokker-Planck equation is quite extensive.

Engineers are just beginning to exploit the results obtained in these areas. The paper under review and several referred to in it are cases in point. Author solves Fokker-Planck equation associated with the *steady-state response* of one- and two-degree-of-freedom suspension systems when input is gaussian white noise. Variance of each mass displacement is then evaluated. It is to be noted that the assumption of steady-state responses simplifies the solution of the Fokker-Planck equation in a striking manner.

Physicists have also been aware of the fact that white noise may be used to characterize an input provided the spectral density is constant over a low pass band whose cut off frequency is several orders of magnitude higher than those which occur naturally in the system. For example, in the Brownian motion problem, the molecular impacts on Brownian particles may be represented by white noise since the frequency of such impacts is many times more rapid than are the changes which can be observed in the particle velocity.

Engineers have been rather reluctant to observe these restrictions on the use of white noise. In mechanical systems which possess mass, it is very difficult to imagine any physically realizable input which would make it possible to assume that the system response (in phase space) at time $t + \Delta t (\Delta t > 0)$ depends *only* upon its position at time t. Yet this follows from the assumption of white noise input. Reviewer feels that author's results must of necessity have a rather limited range of usefulness in engineering.

J. L. Bogdanoff, USA

3521. Caughey, T. K., Sinusoidal excitation of a system with bilinear hysteresis, *ASME Trans.* **82** E (*J. Appl. Mech.*), 4, 640–643, Dec. 1960.

This is the first of three interesting papers concerned with the vibration of systems having a particular form of bilinear hysteresis: the force-displacement law follows the parallelogram $F = k[(1-\mu)x \pm \mu x_0)]$, $F = k[x \pm \mu(R - x_0)]$ for amplitude $R > x_0$; $F = kx$ for $R < x_0$. This paper considers a single-degree-of-freedom system having a spring-law of the above type, subject to sinusoidal excitation. Using the method of Krylov and Bogoliubov, author obtains an amplitude-frequency relationship. For large enough force amplitudes the system has an unbounded resonance; otherwise all solutions are stable. Analog computer results show close agreement.

J. D. Robson, Scotland

Wave Motion and Impact in Solids

(See also Revs. 3458, 3556, 3889, 3917)

3522. Konenkov, Yu. K., A Rayleigh-type flexural wave, *Soviet Phys.-Acoustics* **6**, 1, 122–123 (Brief Communications), July/Sept. 1960. (Translation of *Akust. Zh., USSR* **6**, 1, 124–126, Jan./Mar. 1960 by Amer. Inst. Phys., New York, N. Y.)

A discussion is given of flexural waves propagating along the free edge of a semi-infinite plate, with displacement amplitude decreasing as an exponential function of the distance from the edge. Classical (Lagrange) theory of flexure is used and a simple algebraic equation is deduced which yields the phase velocity of the edge waves. The same results have been obtained in the past [AMR 11(1958), Rev. 3464] from consideration of symmetric flexural waves propagating along an infinite plate strip, in the limiting case of plate width-to-thickness ratio approaching infinity.

D. C. Gazis, USA

3523. Pao, Y.-H., and Mindlin, R. D., Dispersion of flexural waves in an elastic, circular cylinder, *ASME Trans.* **82** E (*J. Appl. Mech.*), 3, 513–520, Sept. 1960.

The methods developed to map approximately the branches of Pochhammer's equation for extensional waves in an infinitely long circular cylinder are extended to the case of flexural waves. They consist in using a grid of simpler auxiliary curves and asymptotic equations for long and short wavelengths. In this manner, a good qualitative view is obtained of the relations between frequency, phase velocity, group velocity, and propagation constant for any branch of the equation, as well as some information as to the shapes of the modes. The necessary expenditure of computation is much less than that required in direct analytical treatment of Pochhammer's equation. As an example the case of Poisson's ratio 1/3 and real propagation constant is treated.

F. Engelmann, France

3524. Miles, J. W., Scattering of elastic waves by small inhomogeneities, *Geophysics* **25**, 3, 642–648, June 1960.

Theory of Rayleigh scattering is extended and applied to the problem of elastic waves caused by small inhomogeneities in an otherwise homogeneous, isotropic medium. Problems of both P- and S-wave incidence are solved. It is found that a change in compressibility acts, in the far field, as a simple source and a change in density as a dipole, while a change in rigidity contributes both simple source and quadrapole.

The approach here given is limited to those cases in which the difference between the acoustic impedances of the medium and the obstacle must be small. Its simpleness and the arbitrariness of the shape of the obstacles assumed are worth mentioning.

Y. Sato, Japan

3525. Treitel, S., Thermal attenuation of nonlinear stress waves, *J. Appl. Phys.* **31**, 2, 391–395, Feb. 1960.

The problem considered is the attenuation of one-dimensional nonlinear stress waves in solids, including thermal effects under the restriction that the plastic strains are small compared to elastic strains. The purpose of the study is to account for the apparent discrepancy between previous analysis, leading to the conclusion that the attenuation coefficient is proportional to the square of the circular frequency, and much experimental evidence, concerning many solids but particularly silicates, which suggests that the attenuation coefficient is proportional to the first power of the

circular frequency. It is demonstrated that the damping of a nonlinear stress wave can be described in terms of two attenuation coefficients: a mechanical coefficient depending on the zeroth, first and second powers of the circular frequency and a thermal coefficient which is a function of the second and third powers of the circular frequency. It is suggested that the thermal attenuation coefficient will be very small; however, the question of its importance must remain open pending further careful experimental investigation of the properties of rock. J. H. Baltrukonis, USA

3526. Healey, J. H., and Press, F., Further model study of the radiation of elastic waves from a dipole source, *Bull. Seismol. Soc. Amer.* **49,** 2, 193–198, Apr. 1959.

Taking into account the results of previous work, author demonstrates one possible mechanism for the origin of the anomalous shear waves by studying two-dimensional waves generated by a single source adjacent to a long slit. Rayleigh waves are thus produced which are transmitted as shear waves in the medium. Proper allowance must thus be made in studies of the mechanism of the focus. G. E. Jarlan, Canada

3527. Miles, J. W., On the response of an elastic half-space to a moving blast wave, *ASME Trans.* **82** E (*J. Appl. Mech.*), 4, 710–716, Dec. 1960.

Investigation stems from interest in the design of structures resistant to the effects of air blast resulting from large explosions. Attention is given to the behavior of a semi-infinite elastic region under the action of an axisymmetrical distribution of pressure that is neither uniform nor steady. Following the introduction of the wave equations for the dilatation and shear potentials, the formal solution of the general problem is derived through the use of integral transform techniques. Because of the complexity of this solution, an approximate solution which is asymptotically valid at great distances is developed. This approximation comprises a part corresponding to the known solution for a two-dimensional pressure pulse moving with constant speed and a part that has importance only where the axisymmetrical pressure pulse is moving with a speed close to the Rayleigh-wave speed.

In comparison with earlier investigations, the present approach is physically more realistic and naturally the analysis involved is more complicated. H. G. Hopkins, England

3528. Klyukin, I. I., Attenuation of flexural waves in rods and plates by means of resonance vibrating systems, *Soviet Phys.–Acoustics* **6,** 2, 209–215, Oct./Dec. 1960. (Translation of *Akust. Zh., USSR* **6,** 2, 213–219, Apr./June 1960 by Amer. Inst. Phys., Inc., New York, N.Y.)

Author's work is concerned with the vibration-isolating effect of resonance vibrating systems (antivibrators) on the propagation of flexural waves in elastic rods and plates. An antivibrator, in its simplest form, is a mass coupled through a cushion (with or without friction) to the elastic medium in which the waves are propagating. Author's experiments show that an antivibrator with a rubber elastic cushion, mounted on thin metal plates, has a vibration-isolating effect over a certain frequency range. It is to be noted that this antivibrator has mass impedance to both rotational and lateral motions. J. Miklowitz, USA

3529. Knopoff, L., and Gilbert, F., Radiation from a strike-slip fault, *Bull. Seismol. Soc. Amer.* **49,** 2, 163–178, Apr. 1959.

Huygens' principle for elastodynamics has been applied to the problem of the radiation resulting from the introduction of a tear fault of finite length into an otherwise homogeneous medium. The fault has the following properties: (1) It is a surface across which the normal stresses vanish; (2) it has a rectangular shape with one dimension increasing at a constant rate in the direction of faulting; (3) the times of initiation and termination of the fault are both finite. The relative displacement on opposite sides of the fault is prescribed to be a step function of time. This configuration may be imaged in the earth's surface by symmetry, so that the problem is reducible to that of a propagating strike-slip fault of finite length in an infinite elastic medium. The observed events are the *P* and *S* waves from the two ends of the fault. Simplified "first motion" responses are computed and compared with solutions derived from the usual theory of force couples.

From authors' summary by G. E. Jarlan, Canada

Soil Mechanics: Fundamental

(See Revs. 3530, 3913, 3916)

Soil Mechanics: Applied

(See also Rev. 3916)

Book—3530. Terzaghi, K., From theory to practice in soil mechanics, New York, John Wiley & Sons, Inc., 1960, viii + 425 pp. $12.

Volume honors Karl Terzaghi's leadership in development of soil mechanics as an important branch of civil engineering and demonstrates the prerequisites and techniques for successful practice of soil mechanics. His career as geologist, teacher and international consultant on soil problems is traced from birth in Austria in 1883 to present. His thorough and imaginative method of working is shown by notes of his associates, his own article on "Consultants, clients and contractors," and selected complete professional reports on Settlement, Bearing capacity, Tunneling, Cofferdams, Earth dams and Stabilization of landslides. His achievements are presented through a review of his discovery of the powerful concept of effective stress and selected professional papers (including some new translations) which show how he established the fundamental principles of soil mechanics and used them in his engineering practice.

Terzaghi's philosophy on the aim, scope and method of soil mechanics is given in his presidential addresses to several international conferences on soil mechanics and the introduction to his classic book, "Erdbaumechanik" (1925). Theory is considered secondary to thorough exploration, critical observation, and sound judgment. Bibliography lists 256 articles (1906–1960).

E. S. Barber, USA

3531. Roza, S. A., Field tests of a rock foundation for a high-head gravitational dam (in Russian), *Gidrotekh. Stroit.* **30,** 2, 21–25, Feb. 1960.

An analysis of shear tests of rock is discussed, carried out on concrete blocks in a gallery in granite at the site of a high gravity dam. The ground-plan dimensions of blocks of 1.1 × 0.9 m were chosen so that the dimensions might be several times the distance between cracks and the mass of work might be considered homogeneous. The tests confirmed the fact that for great normal forces the modulus of shear deformation of rock increases so that a concentration of shear stresses in the region of the downstream toe of a dam may be expected. The rock strength was evaluated for three cases: limit of proportionality, limit of first cracks, and maximum strength. They give a relatively small c (1–6 kg/cm^2), but a shear-strength angle of 44°, 52° and 56°. The modulus of compressibility of the rock mass was 123,000 kg/cm^2.

V. Mencl, Czechoslovakia

3532. Laszlo, R., Hollow pile foundations sunk by vibration method (in Hungarian), *Mélyépítéstudományi Szemle* **10**, 8, 361–366, Aug. 1960.

3533. Selig, E. T., McKee, K. E., and Vey, E., Underground structures subject to air overpressure, *Proc. Amer. Soc. Civ. Engrs.* **86**, EM 4 (*J. Engng. Mech. Div.*), 87–102, Aug. 1960.

Paper presents an analytical procedure for determining the relationship between structural parameters, the soil and the loading with reference to structural failure. Because of the high degree of complexity of soil behavior, the validity of the results may be questionable. This is particularly true for deeply buried structures, since the region of failure may not extend to the surface. No reference is made in the paper to the fact that, due to the formation of a ground arch, additional burial may not result in further overpressure reduction. In summary, the paper may be useful for nuclear blast structural design where the structure is not deeply buried. C. B. Matthews, USA

3534. Blinov, N. F., Nonfreezing liquid piezometer (soil water pressure meter) (in Russian), *Gidrotekh. Stroit.* **30**, 6, 48–49, June 1960.

The well-known method for measuring soil water pressure, e.g. a vertical tube water-manometer placed in a porous medium, is less suitable in large parts of Russia due to the subzero temperatures, occurring during long periods of the year. Author describes a modification, consisting of a steel vessel in the shape of a flat cylindrical box with a perforated side wall, from which the vertical manometer tube emerges. By means of a flexible membrane the vessel is separated in two parts, one connected to the manometer tube, the other, via the perforations, is in direct contact with the soil water. The manometer part is filled up with water together with an anti-freezing compound (presumably a mixture such as used as a cooling liquid in motor-cars).

The piezometer is buried in a few layers of gravel, acting as a filter to avoid clogging of the perforation, while a thermometer in the gravel layer indicates the freezing of the water in the subsoil. Calibrations and field experiences have shown that the instrument gives reliable and accurate results.

R. G. Boiten, Holland

3535. Miklos, J., Safety of statical constructions against tilting failure (in Hungarian), *Mélyépítéstudományi Szemle* **10**, 11, 521–524, Nov. 1960.

Processing of Metals and Other Materials

(See also Rev. 3587)

3536. Eason, G., and Shield, R. T., The plastic indentation of a semi-infinite solid by a perfectly rough circular punch (in English), *ZAMP* **11**, 1, 33–42, 1960.

This is an important extension of work by Shield [AMR 9(1956), Rev. 2189] in which *smooth* flat punch was considered. Isotropic nonhardening rigid-plastic material obeying Tresca yield criterion and associated flow rule is assumed and field theory is developed for conditions of axial symmetry. Solution obtained applies for cases where coefficient of friction between punch and material exceeds 0.139, and is shown to give actual indentation pressure, by theorems of limit analysis. Average pressure is found to be $6.05k$, compared with $5.69k$ for smooth punch, k being shear yield stress. Equations are solved using digital computer, and reviewer hopes that authors will continue their studies and consider other axially symmetric problems, for example, indentation by conical indenter (Rockwell test). J. M. Alexander, England

3537. Singh, B. R., Study of critical velocity of stick-slip sliding, *ASME Trans.* **82** B (*J. Engng. Industry*), 4, 393–398, Nov. 1960.

Theoretical analysis is supported by experimental results on a milling machine, and by means of an analog computer. Suggestions are made for avoiding stick-slip behavior for practical applications. The analytical description parallels the more detailed purely mathematical analysis given by Prof. B. V. Derjaguin, et al. "A theory of stick-slip sliding of solids" [Conf. on Lub. and Wear, October, 1957, London]. J. W. Kissel, USA

3538. MacDonald, A. G., Kobayashi, S., and Thomsen, E. G., Some problems of press forging lead and aluminum, *ASME Trans.* **82** B (*J. Engng. Industry*), 3, 246–252, Aug. 1960.

Several press forgings were made and it was found that the experimental mean forging pressures were in substantial agreement with values predicted by theoretical solutions based on an approximate theory. The forging processes were axial symmetric forging of disks between flat dies and forging in closed dies with several edge effects, such as overhanging flash, with and without flash-edge restriction. The materials were commercially pure aluminum and lead and were chosen because of their respective work-hardening and strain-rate effects at room temperature. It was found further that the local pressures measured in the forging were in good agreement with the theory, but that some local plastic flow tends to equalize the pressure in the body of the forging.

From authors' summary

3539. Kudo, H., An upper-bound approach to plane-strain forging and extrusion: Part 1, *Inter. J. Mech. Sci.* **1**, 1, 57–83, Jan. 1960.

Article deals with suitable technique for finding least upper-bound solution in deformation problems encountered in forging and extrusion fields. Author approximates actual velocity field by use of rigid triangular sections whose interfaces are surfaces of velocity discontinuity. He shows optimum geometrical arrangement as function of various height-width ratios for a unit rectangular deforming region.

Application to case of plane strain compression with rough dies is within 5% of results by slip-line theory. Open die extrusion, forging, heading, and indentation are examined, the latter also showing close correlation with slip-line theory. In each case, the material affected is divided into the most suitable unit regions, each analyzed in terms of the optimum rigid-triangle velocity field, and the mean working pressure versus geometry obtained by summation.

Author presents his results for various unit regions in simple tabular form. This permits application to a variety of problems where work region can be approximated by sum of these component regions. H. I. Fusfeld, USA

3540. Popov, S. M., Approximate method of solution of problems of pressing of profiling plates compressed by heated plastic bodies (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **29**, 37–54, 1960.

As shown by A. Ilyushin, the mathematical equations intervening in the problem of pressing plastic bodies between plane or small curvature profiling plates may be solved relatively easily by an analogy with the sand heap. When the yield point varies, or more generally when the right hand side of the flow equation is variable (e.g., as is the case of heated plastic bodies), the problem complicates. Author examines the integration of this equation (1) in the regions of Coulomb friction, (2) in the region of Prandtl friction, or (3) in the cohesion region. It is shown that with certain approximations the analogy with the sand heap can be also used.

The examination is illustrated with numerical examples of calculation. P. P. Teodorescu, Roumania

3541. Kalliopin, V. V., The machining process as a problem in elasticity (in Russian), *Inzbener. Fiz. Zb.* **3**, 6, 29–34, June 1960.

Author suggests that vibrations in the machine-tool-workpiece system are due to periodic stress variations of the relaxation type. The results of some photoelastic experiments are shown and it is concluded that isochromatic lines are parallel to or coincide with the shear plane. Author considers the elastic region preceding the shear plane and treats the latter as a boundary of the elastic region rather than as an idealized shear zone. By assuming that the lesser principal stress on this boundary is collinear with the resultant cutting force, a shear angle relationship is derived which is identical with that of Lee and Shaffer. Basis for this assumption, however, seems doubtful.

Author claims good agreement with experiment, but in view of the known deficiencies of the Lee-Shaffer theory, this must be regarded with some suspicion. R. C. Brewer, England

Book—3542. Vieregge, G., Cutting of ferrous metals [Zerspanung der Eisenwerkstoffe], Dusseldorf, Verlag Stahleisen *G.m.b.H.*, 1959, xii + 346 pp.

This is an analytical treatise of machining metallurgy on the college level. It includes several contributions from author's work with Opitz (Aachen Techn. Univ.) and Ballhausen (Titanit, Krefeld), NW Germany. It contains about 160, chiefly German, references. Three parts discuss: machining principles; machinability of steel, ferrous alloys and cast iron; and cutting ability of tool materials.

In the first part, the definition of tool geometry is followed by a description of chip formation, account of energy consumed in cutting and transformed into heat, distribution of resulting temperatures, cutting forces, types of tool failure, and tool life. A new concept of machinability testing by wear lines traced as function of speed for a constant cutting time of 10 minutes is developed. Efficiency improvement by coarse feeds, speed within application limits of Taylor formula, proper tool geometry and cutting fluid selection and hot machining are advocated.

Second part shows machinability evaluation by means of speed or secondary phenomena such as: (1) chip deformation ratio; (2) chip formation pattern; (3) finish of machined surface; (4) built-up edge formation; (5) scuffings of machined surface; (6) burrs in continuous cuts; (7) burrs and spalling of machined edges in interior cuts; (8) chip sticking to the tool edge; (9) specific power consumption in cu. cm/HP/min. Author contributes a new machinability classification of 10 types, for which he recommends tool geometries for turning, milling, planing, drilling and reaming. An extensive machinability analysis shows influence of microstructure, heat treatment, grain size, hardness, inclusions, hot and cold work, alloying elements and processing methods. Machinability of various ferrous materials is subsequently listed.

Third part describes various tool materials and their grades. Reviewed are tool and high-speed steels, hard cast alloys, cemented carbides and oxides, and industrial diamonds. Grinding wheels and all abrasives are left out. Author describes manufacture or heat treatment, composition, properties, classification and application of various tool material grades. For cemented carbides he uses new ISO classification. Book ends with a survey of common tool evaluation methods used in physical and in cutting laboratories.

Book contains lists of names and topics, and also of symbols. A. Niedzwiedzki, USA

3543. Kobayashi, S., Herzog, R. P., Eggleston, D. M., and Thomsen, E. G., A critical comparison of metal-cutting theories with new experimental data, *ASME Trans.* **82** B (*J. Engng. Industry*), 4, 333–347, Nov. 1960.

The following alloys were investigated in orthogonal metal-cutting tests at varying cutting speeds, rake angles, and feeds: Steel SAE 1112 annealed and as-received; steel SAE 1020 as-received; steel SAE 4135, annealed, as-received, and Rockwell hardnesses 27 and 35–37; aluminum alloy 2024-T4; aluminum alloy 6061 in the 0 and T6 conditions; alpha brass. The new data obtained in the present investigation under wide variation of test conditions (speed for SAE 1112 annealed and as-received was varied from 0.083–1010 fpm) confirmed earlier observations that the shearing stresses are independent of the test conditions investigated. These observations were supported by theoretical considerations. Correlation of metal-cutting data with compression data on the basis of the incremental or distortion-energy theory was good for the ductile metals. Less perfect correlation was observed with SAE steel 4135 and aluminum alloy 2024-T4. It was found further that none of the known theoretical angle relationships were in agreement with all of the experimental data.

From authors' summary

3544. McDonald, W. J., and Murphey, B. F., The deformation process in metal-cutting, *ASME Trans.* **82** B (*J. Engng. Industry*), 3, 253–258, Aug. 1960.

An analysis of the orthogonal chip process for a strain-hardening material is presented together with a qualitative evaluation of the effects of temperature increases and flank rubbing. An expression is derived for the average stress on planes through tool point ahead of the shear plane. The authors postulate that strain-hardening requires that a stress-reinforcing phenomenon be present and this requires the shear to take place is a region of increasing stress. The rate of increase required is postulated to depend on the final strain imparted to the chip. Data from the literature are presented to support this view. The conclusion is drawn that the strain imparted to the chip is a measure of the deviation of the shear angle from the Merchant minimum-energy condition.

From authors' summary by F. Garofalo, USA

3545. Okushima, K., and Fujii, Y., Physical properties of ceramic tool materials (especially on the adhesion of ceramics), *Bull. JSME* **3**, 12, 560–565, Nov. 1960.

This paper describes the adhesion of cutting tools at high temperatures from the results of empirical cutting data and fundamental test on the adhesion between cutting tool tips and work materials. The adhesive tests were run in vacuum, except where noted, by means of the Vickers hot hardness testing machine.

In consequence, authors found that the critical temperature for adhesion was affected by the chemical composition of ceramics and kinds of metals and that the strength of the interface between ceramic tips and metals was weaker than in the case of carbides and this fact was recognized as one of the reasons why the crater wear and built-up edge in ceramics were less than in carbides.

From authors' summary

3546. Sasaki, T., and Okamura, K., The cutting mechanism of abrasive grain: Part 1, Experimental observations of the stock removal and the swell-up phenomena, *Bull. JSME* **3**, 12, 547–554, Nov. 1960.

The investigations of the basic cutting mechanism in the finishing processes using grains for the cutting edge are the fundamental measures for improving the finishing efficiency and for elevating the smoothness of a finished surface. The model cutting tests of grains have been carried out under such conditions that the cutting edge angle and the cutting speed may reproduce the original form of the cutting states of the finishing operations such as grinding, superfinishing and single-point cutting.

As the result of these tests, the relations between the stock removal or the swell-up and the cutting edge angle or the cutting speed are clarified, and the influence of cutting conditions on the

ratio of the tangential and the normal cutting force is found. Moreover, the relation between the cutting mechanism and the cutting speed is obtained. From authors' summary

3547. Shtepanek, K., Steady sliding motion (in Russian), *Chekhosl. Tiazh. Prom-st'* no. 3, 38–45, 1957; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3555.

Problems are examined of the steady motion of sliding fitted parts of metal-working machine tools. The causes are investigated of the origination of unsteady displacement of such machine-tool element. The unsteady state in this context is assumed to be the appearance of chattering motion, interrupted by periods of rest. Chatter can be explained by graphical considerations as starting from the form of the characteristic curves, expressing the relationship between the speed of sliding motion and the frictional forces. It is underlined that correct conclusions can be derived only from dynamic, and not static, considerations. An approximate, theoretical analysis of the process is described, leading to consideration of a second-order, linear differential equation. The experimental investigations which have been made in this regard agree well with the theoretical calculations. The most suitable method of stabilizing the process of sliding motion is to vary the dynamic characteristics, utilizing the possibility of employing polarized lubricating oils. The polarized substances discovered by prolonged experimentation have enabled the creation of special, highly-polarized lubricating oils. The stability of the lubricating-oil film produced by these oils considerably reduces wear (abrasion) and enables in many cases (lathe rests, grinders) a highly-uniform advance motion to be obtained.

N. N. Krasovskii
Courtesy Referativnyi Zhurnal, USSR

Book—3548. Roll, F., edited by, Handbook of foundry technology, Vol. 1, Part 2: Materials, status and problems in standardization [Handbuch der Giesserei-Technik, Stand und Probleme der Normung], Berlin, Springer-Verlag, 1960, xi + 363 pp. DM 66.

Fundamentals of the cast-iron carbon alloys are comprehensively discussed in this second part of the first volume. Gray iron, chilled iron, and malleable iron are systematically reviewed. Reviewer feels that technical developments are masterfully and concisely integrated into this reference volume.

The presentation is readily understandable, and the authors obviously took great pains to select illustrative and tabular material with care. The data on wear and elevated temperature properties are especially timely.

The information on rolls is unequalled in its scope and lucidity, and the excellence of the photomicrographs cannot be overemphasized.

Designers and engineers, as well as foundrymen, will find this volume a valuable addition to their technical library. Contributors, such as Wittmoser and Patterson, rank among the foremost experts in contemporary Europe.

This reviewer would have included a more detailed index for so important a handbook. However, this is a minor flaw and publication of the remaining volumes is anticipated.

H. J. Heine, USA

Fracture (Including Fatigue)

(See also Revs. 3544, 3577, 3592)

3549. Tucker, J. T., Jr., Coulter, E. E., and Koolstra, L. F., Effect of wall thickness on stress-rupture life of tubular specimens, *ASME Trans.* **82** D (*J. Basic Engng.*), 2, 465–476, June 1960.

Stress-rupture data obtained from tubular specimens stressed with internal pressure are compared with data from standard tension-bar specimens from the same heats of material. Agreement between the data of the two types of specimens is poor for thick-walled tubes when the hoop stress in the tube wall is calculated on an average stress basis. Better agreement is obtained with thin-walled tubes. These results show that any design formula that neglects the variation of stress through the thickness of a tube wall is unsatisfactory for thicker tubes.

A dimensionless parameter method is presented which provides satisfactory correlation of the data for three materials, four test temperatures, and a wide range of wall thickness. Several areas in which additional research would be of value are discussed.

From authors' summary by Y. Hori, Japan

3550. Wessel, E. T., The influence of pre-existing sharp cracks on brittle fracture of a nickel-molybdenum-vanadium forging steel, *Trans. Amer. Soc. Metals* **52**, 277–306, 1960.

Tests provide measure of fracturing behavior for varied specimen configuration, size, and notch preparation. The largest of these, plate specimens of test section 5/8 in. thick, 4 in. wide, were prepared on one edge with a natural crack inserted by local chilling and wedging. When pulled in tension, fast fracture was always found to initiate from the natural crack in preference to the corresponding balancing notch in the other edge. With the natural crack type of flaw, strength fell from above to well below the yield strength level with rather small decrease in temperature. A broader transition range was found with other specimens and notches—particularly small notched tensile rounds and Charpy impact. A dependence of fracture strength on inverse square root of crack length was found in accordance with considerations of Irwin fracture mechanics. Fracture surface appearance and morphology is characterized with respect to temperature ranges above and below the strength ratios transition.

J. M. Krafft, USA

3551. Kachanov, L. M., On the fracture time under conditions of creep (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 5, 88–92, 1960.

Paper is a continuation of a previous publication of the author [AMR 4(1960), Rev. 1758]. It contains a theoretical examination of the laws defining the fracture time of a rod under uniaxial tension and different conditions of loading. The cases examined are: constant strain-rate, a step function of loading and various conditions of relaxation. The fracture picture of a brittle thick-walled tube is also examined. Finally, the influence of thermal stresses on the fracture time is discussed.

In the beginning author defines the various modes of fracture, i.e. brittle, nonbrittle and viscous. The speed of the front of fracture is described by the integrodifferential relation

$$dv/dt = -(\sigma^n_{max})\left[\int_0^t \sigma^n_{max}(\tau)\,d\tau\right]^{-1}_t$$

In a homogeneous tension field dt tends to zero and the front of fracture is propagated abruptly. In heterogeneous conditions of tension the fracture front proceeds with finite velocity. This consideration is a correction of the previous paper of the author.

In the case of tension fracture under constant strain-rate, author establishes relations expressing the fracture time t^*, and the fracture deformation ε^*, for different relative values between the coefficients n and m, where m is the exponent of the well-known creep function.

Formula expressing ε^* is compared with empirical relation established previously by A. B. Stanoukovich, through a series of experiments on various alloys. The validity of these formulas ex-

cludes the expansion of definition of N. Hoff concerning the introduction of a limited fracture deformation.

After a concise consideration of the case of brittle fracture by a step function of loading author examines cases of brittle fractures under different conditions of relaxation, i.e. simple relaxation and a step relaxation program. During this process of loading it is assumed that the various parts of the relaxation curve after each application of one overload σ_n at time t_n are obtained by parallel displacement of the initial relaxation curve.

Above theory is applied to the case of brittle fracture of a creeping thick-walled tube, subjected to internal pressure. The integrodifferential equation obtained for cases of exponent of creep $m > 2$ is solved numerically by applying Euler's formula for the case of tube with an external diameter of double the internal diameter and values of $m = 4$ and 6. Plotted curves show a slow motion of fracture front at the beginning of fracture which takes the character of an "avalanche" at the final stage.

P. S. Theocaris, Greece

3552. Garofalo, F., Creep-rupture behavior of notched and unnotched specimens of types 304, 316, and 321 austenitic stainless steels, *Proc. Amer. Soc. Test. Mat.* **59**, 957–972, 1959.

Author studies creep rupture strength of austenitic steels at 1100 F and 1500 F for notched and unnotched specimens. In elevated temperatures, a notch may either strengthen or weaken a material. Three test materials exhibited a measurable degree of notch strengthening for all stresses at the 1500 F test temperature. At 1100 F there is a tendency for slight notch weakening between 100 and 1000 hours rupture time. Examination of type 321 test specimens sectioned before rupture indicates rupture initiates just beneath the notch surface, and propagates intergranularly toward the notched surface and toward the interior simultaneously. Large plastic deformation follows after the propagating crack is apparently arrested, creating biaxial stresses at the specimen center. A new crack is initiated here which propagates to join the arrested crack. Intergranular-type rupture in the tests indicates the grain boundary influences the rupture mechanism for the notched and unnotched specimens. L. W. Smith, USA

3553. Barenblatt, G. I., Concerning equilibrium cracks forming during brittle fracture. The stability of isolated cracks. Relationships with energetic theories, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **23**, 5, 1273–1282, 1959. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

3554. Mishler, H. W., Monroe, R. E., and Rieppel, P. J., Studies of hot cracking in high-strength weld metals, *Welding J. Res. Suppl.* **40**, 1, 1-s–7-s, Jan. 1961.

3555. Johnson, A. E., Henderson, J., and Mathur, V. D., Complex stress creep fracture of an aluminium alloy, *Aircr. Engng.* **32**, 376, 161–170, June 1960.

The purpose of the investigation was to examine the tertiary creep and the creep fracture characteristics of an aluminium alloy to specification B.S.2L42, subject to complex stressing at 200 °C. The scope of the work involved seven pure torsion, pure tension, and combined tension and torsion creep tests, of durations between 300 hrs. and 3,000 hrs., on the aluminium alloy at 200 °C., and analysis of the results.

From authors' summary

3556. Beard, D. B., Meteoritic impact, *ARS J.* **31**, 1, 87–88 (Tech. Notes), Jan. 1961.

The impact of meteoroids on a space vehicle skin is examined from a consideration of the different physical processes by which energy transfer can occur. It is shown that only evaporation is significant, that erosion is negligible, and that puncture is less likely than previously thought by many authorities, the threshold thickness in centimeters being only 0.6 cm for one puncture per year per 100 m^2 of surface. From author's summary

3557. Garofalo, F., Effect of environment on creep and creep-rupture behavior of several steels at temperatures of 1000 to 1200 F, *Proc. Amer. Soc. Test. Mat.* **59**, 973–984, 1959.

Author presents test data on several ferritic and austenitic stainless steels tested in air, gaseous atmospheres and vacuum. Results indicate creep and creep rupture properties are not affected by environment within limits of testing. Author describes test apparatus, giving details for assuring axial load and controlled atmosphere. Author states environment has no effect on minimum creep rate or on the rupture life of the specimen. Slope of log stress versus log rupture time for the steels tested was unchanged for all environments, indicating that intergranular oxidation did not decrease creep rupture strength.

L. W. Smith, USA

3558. Lipsitt, H. A., Forbes, F. W., and Baird, R. B., Crack propagation in cold-rolled aluminum sheet, *Proc. Amer. Soc. Test. Mat.* **59**, 734–754, 1959.

Low-cycle, high-stress fatigue tests in fluctuating tension were performed on transverse and longitudinal specimens of sheet 1100 H18 aluminum alloy. The kinetics of growth of a fatigue crack initiated at a mild semicircular notch were determined at several stresses from stop-motion photographic records.

The data indicate that the growth of a fatigue crack is not linear (on a semilogarithmic plot) in these tests, or even continuous. Crack growth is seen to consist of short bursts of growth followed by periods of no measurable growth. In the initial stages, the growth bursts are proportional to the stress and the rest periods inversely proportional. H. J. Grover, USA

3559. Kyrala, A., Fundamentals of a stochastic fatigue theory (in German), *Öst. Ing.-Arch.* **14**, 3, 204–218, Oct. 1960.

Subject matter is material having uniformly distributed incremental flaws and errors so that for any cycle of external load there will exist merely a scalar relationship between state of stress and load (exact meaning of this statement is not clear to reviewer). Author considers random variations of state of stress in a Haigh-Westergaard diagram. In addition to this he makes a series of fundamental assumptions such as the following. Fracture shall occur whenever representative point trespasses across boundary of certain circular cylinder whose axis coincides with main diagonal of diagram. Stress variations in amplitude and angular direction are entirely at random. Author calculates probability of survival, thus arriving at something similar to ordinary Woehler curve of fatigue. He also investigates influence of mean stress different from zero, this implying certain weight function with respect to amplitude but not direction of stress. Making additional assumptions, author generalizes theory, taking account of progressive nature of fatigue crack. He also shows that Miner-Palmgren's cumulative damage theory is within reach of his fundamental conception of fatigue phenomena. Further discussion relates theory to recent observations regarding fatigue, e.g. its close connection with diffusion of dislocations and with surface properties of test piece.

In reviewer's opinion, author's theory, although containing new and attractive features, is too sketchy to permit final judgement.

Observed misprint: quantities N and n in first eqs. III.7 and III.8 should change place. F. K. G. Odqvist, Sweden

3560. Das, P. K., Accelerated fatigue testing—A new technique for determination of fatigue limit under progressive loading, *J. Instn. Engrs., India* **40**, 5 (Part 1), 377–389, Jan. 1960.

3561. Baird, R. B., Forbes, F. W., and Lipsitt, H. A., Tensile and fatigue properties of laminate sheet structures, *Proc. Amer. Soc. Test. Mat.* **59**, 755–766, 1959.

Tension and fatigue (cyclic tension at 8 cpm) tests were made on laminates of adhesive-bonded 1100-H18 foil. Resulting strength values and failure appearances are different for the laminates and solid sheet material. In several respects, the laminates show potentially valuable properties, particularly in fatigue.

H. J. Grover, USA

3562. Tavernelli, J. F., and Coffin, L. F., Jr., A compilation and interpretation of cyclic strain fatigue tests on metals, *Trans. Amer. Soc. Metals* **51**, 438–450, 1959.

By plotting to logarithmic scales, both the number of cycles at failure (N) and the plastic strain range (ΔEp), the authors have established that a relationship $N^{\frac{1}{2}} \Delta Ep$–constant best fits all available data. Cyclic-strain fatigue data from several investigators and the authors' work agreed regardless of the metals tested, the temperature of testing or the manner of testing.

When the fracture strain value was plotted on the fatigue curve for N of 1/4 cycle, good agreement results, which provides a very simple method for predicting the fatigue behavior of a metal.

This was a most interesting and significant paper.

J. N. Thompson, USA

3563. Rabinovich, A. L., and Bilik, Sh. M., Determination of the limiting strength of ceramic tubes subject to compression (in Russian), *Vestnik Mash.* **40**, 4, 39–44, 1960.

3564. Takenaka, Y., Fatigue of metals under repeated finite strain, *Bull. JSME* **3**, 12, 419–424, Nov. 1960.

In order to clarify the mechanism of fatigue phenomenon, fatigue tests of mild steel and brass specimens under various constant amplitudes of repeated plastic strain and two other related tests were carried out. The following is the summary of these test results.

(1) In the earlier stage of test, strain-hardening will progress, but subsequently the rate of stress increment will decrease gradually and the stress will saturate to a certain constant value, which corresponds to its strain amplitude.

(2) The mutual relations among the saturated stresses, the strain amplitudes and the number of cycles up to fracture can be graphically represented by straight lines with respect to the log-log scale.

(3) In the fatigue tests under two-step-plastic-strain amplitude, strain-softening can be observed when the amplitude of the second step is smaller than that of the first step. And it can be also observed that the first step always reduces the life in the second step.

From author's summary

3565. Kawamoto, M., Nakagawa, T., and Kohama, H., Fatigue strength under multiple repeated stress (in the case of double change of amplitude in two stress levels), *Bull. JSME* **3**, 12, 425–431, Nov. 1960.

The problems of the fatigue of materials have been studied by many investigators, but there still remain many unknown factors, especially on the damaging effects due to the repeated stress with varying amplitude. In this study, authors carried out the fatigue tests on the medium carbon steel by superposing the higher stress reversals upon the fundamental repeated stress levels in order to discuss the process of fatigue stressing, and investigated the influence of the cycle ratio of the primary stress, the secondary higher stress level, and its reversals on the cumulative cycle ratio to failure.

As a result, it has been found that the more the cycle ratio of the primary stress amplitude is and the lower the secondary stress level is, the greater the cumulative cycle ratio to failure becomes.

Also these test results are interpreted by the use of the cycle ratio-damage curves (D-R curves).

From authors' summary

Experimental Stress Analysis

3566. Dose, A., Methods of plane photoelasticity (in German), *Z. Flugwiss.* **8**, 10/11, 294–307, Oct./Nov. 1960.

Paper deals with application of optical interference effects as supplement to conventional photoelastic methods in determining individual stress components needed for complete solution of plane problems. Theory of interference of light rays reflecting from two surfaces of transparent model is developed. Formation of Moiré lines by superposition of interference patterns obtained at two different loads is demonstrated, and determination of principal stress sum from Moiré lines is explained.

As example of application, simple plane problem is solved by two different methods. Two-model method employs optically birefringent material (VP1527) to produce stress pattern giving principal stress difference, and insensitive material (Plexiglas) to produce Moiré patterns, Solution is obtained from measured stress sum and difference. Second method employs one model of birefringent material to produce both types of patterns. Separate interference of the two polarized light components produced in birefringent material is used to obtain two Moiré patterns, following method of D. Post. Principal stress sum obtained from these two patterns is combined with conventional photoelastic data to obtain solution. Reasonably good interference patterns could be obtained only if model surfaces were very accurately ground and polished. Static checks were within 8 to 12 per cent. Methods described are essentially variations of methods used by Post.

R. Guernsey, USA

3567. Murakami, Y., and Kawabe, T., Photoelastic study on flat bars with V-notches on both edges subjected to pure bending, *Bull. JSME* **3**, 12, 410–415, Nov. 1960.

Flat bar specimens of Phenolite with V-notches on both egdes were subjected to pure bending and the stress concentration factors under various conditions were measured by the photoelastic method. To determine the fringe orders at the base of notch, several bending moments were applied. Similar to the experimental results in tension, the stress concentration factor is the larger, the smaller the root radius, its variation being extremely steep for the values of ρ/b less than 0.3. The included angle has a little influence in the region between 0° and 90°, and as it exceeds 90°, the stress concentration factor diminishes gradually. The depth of notch has such an effect as to give the stress concentration factor its maximum value when the value of t/b is nearly 0.15 to 0.25.

From authors' summary

3568. Linge, J. R., Photoelastic measurement of surface strain; investigation of a direct method using an optically sensitive material bonded to the metal component: Parts 1, 2 and 3, *Aircr. Engng.* **32**, 378, 216–221, Aug. 1960; **32**, 379, 261–270, Sept. 1960; **32**, 380, 295–298, Oct. 1960.

The technique described in this paper consists of the examination of surface strains in a metal component with optically sensitive material bonded to the component and the analysis of the photoelastic pattern produced under load by means of polarized light reflected from the surface of the metal.

The original investigations cover in considerable detail the development of the technique and the results obtained, using the photoelastic materials Catalin 800, C.R. 39, and the Marco Resin, S.B.26C, and S.B.28C, in conjunction with light alloy, magnesium and mild steel.

The fundamental problem of producing good adhesion between the photoelastic material and the metal surface coupled with satisfactory light reflexion from the latter comprised the major part of the initial investigations.

Results of the measurement of both elastic and plastic stress concentrations at holes in plates subjected to uniform tension are presented, together with a qualitative analysis of the effect on stress distribution of the variation of the pin-to-hole clearance in lugs.

The term "Metoplastic" is suggested to describe concisely the use of compound specimens for the photoelastic applications considered. From author's summary

3569. Walter, H., Photoelastic investigation of rigid-frame knees (in German), *Bauingenieur* **35,** 3, 81–85, Mar. 1960.

3570. Morse, S., Durelli, A. J., and Sciammarella, C. A., Geometry of Moiré fringes in strain analysis, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 4 (*J. Engng. Mech. Div.*), 105–126, Aug. 1960.

Fundamental equations are derived for interpreting two-dimensional strains and rotations from Moiré fringe patterns and the results are presented in graphical form. The analysis is applied to a circular disk under diametral compression.

G. Gerard, USA

3571. Vinckier, A., and Dechaene, R., Use of the Moiré effect to measure plastic strains, *ASME Trans.* **82** D (*J. Basic Engng.*), 2, 426–434, June 1960.

The distribution of plastic strains over a surface can be determined from the interference fringes that arise when an underformed grid is superimposed on a deformed grid. The paper shows the theory on which the method is based, as well as examples of the use of the method. J. D. Lubahn, USA

3572. Kodama, M., and Sakamoto, M., On the detection range of strain figures and their characteristics, *Bull. JSME* **3,** 12, 415–418, Nov. 1960.

3573. Wells, J. W., and England, H. B., Elastic model design of the B-58 airplane, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 4 (*J. Engng. Mech. Div.*), 153–179, Aug. 1960.

This paper outlines the extensive elastic model test program used in the design of highly redundant structure on the B-58 airplane. Considerations in the design of the various models on the program are listed and several unique methods of obtaining and presenting test data are shown. Scale factors for both structure and loadings are developed in detail.

From authors' summary

3574. Drexler, J., A contribution to the lever-system design for the airframe strength testing, *Zpravodaj Vzlu* **1,** (19), 23–38, 1960.

At present, most of the time required for an airframe testing program is expended on simulating the real flight conditions of the specimen.

One way of designing the testing apparatus may be accomplished by using mechanical linkages to realize the load distribution on the specimen according to the test requirements. In fact, the linkage system substituted the required aerodynamical and mass loads by a corresponding spectrum of concentrated forces.

In flight conditions, the aerodynamic forces are reacted by the mass; simulating such conditions results in fixing the test specimen by linkages only. Consequently, the final information on stiffness characteristics to be carried out is often being invalidated by various adverse phenomena; the last are due to the realization of the loading process itself as well as to the random factors.

The analytical study deals with problems relative to the virtual motions of the specimen inside the test frame, paying attention to application of advanced statistical methods. It is shown that both the mechanical imperfection of the lever system and the reversibility of the hydraulic loading device may provoke uncontrolled variations up to 7 per cent of the applied force signal. Some practices in designing the lever system are presented to reduce the mentioned variations to an acceptable minimum.

From author's summary

Material Test Techniques

(See also Revs. 3536, 3542, 3549, 3550, 3552, 3557, 3587, 3592)

3575. Kuz'menko, V. A., On the dynamic method of determining the Young's modulus at high temperatures, *Indust. Lab.* **25,** 9, 1160–1163, July 1960. (Translation of *Zavod. Lab., SSSR* **25,** 9, 1109–1110, Sept. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Experimentally, the author finds only 813% increase in Young's modulus measured on the basis of longitudinal frequency of vibration of cylindrical specimens when the temperature is 50% lower at the end phases as compared with the nodal section. He explains this analytically and discusses effects of errors in torsional and flexural measurements of vibrational frequency for computation of moduli. Some of the meaning of the article is lost in translation and evidently a few lines of type were omitted at the top of page 1162. T. J. Dolan, USA

3576. Sachs, G., Sessler, J. G., Pray, R. F., and Yeh, T. H., Relations between the notch tensile strength of cylindrical and prismatic specimens of titanium alloys and heat-treated steels, *ASME Trans.* **82** D (*J. Basic Engng.*), 2, 401–410, June 1960.

3577. Tavernelli, J. F., and Coffin, L. F., Jr., Density measurements on strain-cycled 2S aluminum, *Proc. Amer. Soc. Test. Mat.* **59,** 952–956, 1959.

The change in density was employed as a technique for the study of fatigue damage in 2S aluminum for various amplitudes and repetitions of fully reversed cyclic strain. Following diametral-strain amplitudes as large as 10 per cent for up to 80 per cent of the fatigue life, density measurements were made by a method sensitive to ±0.02 per cent. Density variation were found to be negligible. From authors' summary by T.-S. Liu, USA

3578. Taniguchi, O., Mori, Y., Hashimoto, R., and Sakata, M., Hot spin tester, *Bull. JSME* **3,** 11, 299–304, Aug. 1960.

A hot spin tester enables the authors to obtain precise experimental data on strength and creep properties of rotating disks made of high-temperature alloys. The test specimen, mounted on a flexible shaft with its axis vertical in a vacuum furnace, is driven by a geared motor, the speed being controlled automatically by electric circuit. Maximum speed is 25,000 rpm, and a uniform specimen temperature of 2000 °C can be attained in the electric furnace.

The novel approach centers about the measurement of radial displacement of the disk when rotating at high speed and temperature by the use of a special microscope incorporating a relay lens. Extremely high accuracy of measurement is claimed. For bursting tests of small disks an air turbine attachment is available, allowing speeds up to 100,000 rpm. H. J. Heine, USA

3579. Ovsyannikov, B. M., Stolyarov, V. A., and Timoshuk, L. T., The influence of geometrical parameters of conical diamond penetrators on the results of hardness measurements of metals, *Indust. Lab.* **25,** 8, 1040–1042, July 1960. (Translation of *Zavod. Lab., SSSR* **25,** 8, 996–998, Aug. 1959 by Instrument Society of America, Pittsburgh 22, Pa.)

Rockwell-C indentor's variation of apex angle (α) and variation of radius of curvature (ρ) are evaluated. For $\alpha = 120° \pm 0°20'$ and $\rho = 0.200 \pm 0.010$ mm, deviation of $\pm 1/2\%$ of Rockwell C hardness is found. Figures show dependence on absolute value of hardness. Pertinent literature since 1951 is reviewed.

F. Forscher, USA

3580. Breyer, H., Porosity and frost resistance of concrete (in German), *Allgemeine Bautztg.* **15,** 623, 1–6, Apr. 1960.

After stressing the importance of a reliable test for frost resistance of concrete, author shows that the best results can be reached with the water-saturation-value (S-value), this corresponding exactly to the practical behavior of concrete to frost damage. Such damage can only be cut down by lowering the porosity and hygroscopicity of concrete. By creating an inhomogeneous pore structure, the water saturation value can be reduced and the concrete be made more resistant to frost.

A. Erdely, Argentina

3581. Haynes, C. W., and Valdez, P. J., Rocket motor case material evaluation by pressure vessel testing, *Aerospace Engng.* **19,** 12, 30–36, Dec. 1960.

Properties of Engineering Materials

(See also Revs. 3470, 3486, 3542, 3557, 3558, 3561, 3562, 3575, 3576, 3578, 3641, 3702, 3882)

3582. VerSnyder, F. L., and Guard, R. W., Directional grain structures for high temperature strength, *Trans. Amer. Soc. Metals* **52,** 485–493, 1960.

Authors investigate effect of directional grain structures on the high-temperature creep-rupture properties of a cast alloy of Ni 75.5–Cr 21–Al 3.5 wt % nominal composition. Directionally solidified cast structures having grain boundaries mainly parallel to the direction of stress (longitudinal structures) gave, in comparison with equi-axed structures, greatly improved ductility (20–40% against 0.3–1.5%), longer life to rupture, higher rupture strength, but greater rates of creep. Directionally solidified structures stressed in a direction transverse to the grain boundaries (transverse structures) had creep rates, in the initial stages, that were similar to those of longitudinal structures, but rupture times similar to those of equi-axed structures. Authors conclude that the creep-rupture properties are related primarily to the direction of the grain boundary relative to that of the stress and not to any preferred crystal orientation.

A. L. Titchener, New Zealand

3583. Bush, G. W., and Lindsay, R. W., Tensile properties of copper-bearing low carbon steel, *Trans. Amer. Soc. Metals* **52,** 422–433, 1960.

Studies of 5 heats (100 lb) of low-carbon, deep-drawing steel having copper in range 0.002–0.48 per cent showed that when copper exceeds limit in range 0.1–0.2 per cent, yield and ultimate tensile strengths increase, whereas elongation and strain-hardening modulus decrease.

G. V. Smith, USA

3584. Eberle, F., and Makris, J. S., Fabrication and annealing factors affecting grain size of 18Cr8Ni-Ti superheater materials in steam boilers, *ASME Trans.* **82** D *(J. Basic Engng.),* 4, 855–866, Dec. 1960.

The effect of cold deformations as encountered in tube and superheater fabrication and of temperature and time of annealing on the grain-size characteristics of 18Cr8Ni-Ti is demonstrated by laboratory experiments with material from six heats of steel. It is shown that cold-drawn tubing retains a relatively uniform small grain size at annealing temperatures up to about 1900 F to 1950 F and that above this temperature individual grains begin to grow at an accelerated rate, leading to a mixed grain-size structure. Annealing times between 5 and 15 minutes caused only insignificant differences in the over-all grain size, but extension of exposure to 30 minutes produced a noticeably larger grain structure. Small cold deformations as may be introduced into the material by tube straightening can, when followed by a final anneal, cause excessive localized grain enlargements. Observations pointed to the possibility that materials with high Ti/C ratios may retain a predominantly small grain size at annealing temperatures as high as 2050 F.

From authors' summary

3585. Kinsey, H. V., The creep and rupture properties of three cast copper-base alloys between 550 and 650 F (290 and 345 C), *Proc. Amer. Soc. Test. Mat.* **59,** 940–951, 1959.

The creep and rupture properties of a nickel bronze Ni-Vee A, a leaded nickel bronze Ni-Vee C and a copper-base casting alloy "Navy M" have been measured over the temperature range of 550 to 650 F (290 to 345 C). The effect of an aging treatment on the creep and rupture properties of the nickel bronze has also been determined. Due to excessive scatter of results it has only been possible to observe certain trends. The nickel bronze has better creep and rupture properties than either of the two alloys tested at these temperatures. The heat treatment used for this nickel bronze causes a deterioration of its rupture properties.

From author's summary by T.-S. Liu, USA

3586. Pertsovskii, N. Z., Kinetic deformation and breakdown of copper alloys subject to tension (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, Metallurgiya i Toplivo* no. 6, 43–51, Nov./Dec. 1959.

3587. Tietz, T. E., Mechanical properties of a high-purity lead and a 0.058 per cent copper-lead alloy at elevated temperatures, *Proc. Amer. Soc. Test. Mat.* **59,** 1052–1071, 1959.

Properties were determined as part of evaluation of lead as a structural and/or radiation shielding material. Paper appears to contain much data, constituting a significant addition to that available. Results indicate that strain rate and grain size are important factors affecting properties of lead in range of 100–325 °F, but the strain rate was varied by a factor of only 10 (0.05 to 0.005 per min.) and each alloy was reported in only 1 grain size. Fracture strength was reported as zero, but was nondeterminable as area approached zero. Reviewer suspects that on a microscale the tensile stress-strain curves would tend to be asymptotic to the stress axis. Curves for copperized lead show interesting multiple maxima, "caused possibly by recrystallization of the finer grain-size copperized lead during test."

C. C. Osgood, USA

3588. Adda, Y., Beyeler, M., and Kirianenko, A., Effects of stress on the variations in the chemical composition of an alloy formed by diffusion between uranium and copper (in French), *C. R. Acad. Sci. Paris* **250,** 1, 115–117, Jan. 1960.

3589. Gobin, P., and Montuelle, J., Existence of temporary relaxation of aluminum-zinc alloys after hardening (in French), *C. R. Acad. Sci. Paris* **249,** 23, 2554–2556, Dec. 1959.

3590. Gobin, P., and Montuelle, J., Study of the temporary relaxation in pure aluminium and in hardened aluminium-zinc alloys (in French), *C. R. Acad. Sci. Paris* **249,** 25, 2772–2774, Dec. 1959.

3591. Doyle, W. M., Structural aluminium alloys for high speed flight, *J. Roy. Aero. Soc.* **64,** 597, 535–548, Sept. 1960.

3592. Romualdi, J. P., and D'Appolonia, E., Effect of internal heating on the fatigue life of titanium, *Proc. Amer. Soc. Test. Mat.* **59,** 723–733 (Tech. Pap.), 1959.

Experiments were conducted on effect of internal heating on the rotating-bending fatigue properties of RC-15 titanium. Temperature and deflection were continuously recorded during tests under isothermal conditions, and tests under nonisothermal conditions at speeds from 1000 to 10,000 cpm. Results are discussed in terms of the apparent effects of internal heating during the testing.

H. J. Grover, USA

3593. Laszlo, T. S., and Klamkin, M. S., Determination of the temperature dependence of material properties in image furnaces, *Solar Energy* **4,** 3, 20–21, July 1960.

A special testing method is described which makes it possible to determine a property of a specimen for narrow temperature intervals from measurements in the wide-range temperature distribution of an image furnace. The determination is based on the measurement of the property at several different flux levels of known temperature distribution.

From authors' summary

3594. Kennedy, A. J., Graphite: a future structural material, *Aero. Quart.* **11,** 4, 309–332, Nov. 1960.

Graphite is a material with unique high-temperature properties. Its strength and modulus increase with temperature up to about 2000–2500 °C, in which range it exhibits a higher strength than any known material. The development of new types of graphite (such as pyrolytic graphite, deposited from the vapor) and impregnated graphites are both significant to future technology. The highly-oriented pyrolytic graphites in particular, with their marked thermal and mechanical anisotropy, and their superior mechanical properties (60×10^3 lb./in.^{2} strength at 2750°C., with 60 per cent ductility) offer distinct possibilities, particularly in composite structures. Graphite sublimes directly from the solid to vapor phase at 3700 °C at atmospheric pressure. As the sublimation energy is high, it is, at least in theory, a very efficient ablating material. It also has a high creep resistance. Surface reactions limit its value, particularly in oxidizing environments, and coatings, or other methods of surface protection, are of high importance. The modulus of graphite is low, being about one-half of that for lead at room temperature, increasing with temperature to a maximum in the region of 2200 °C. The properties vary in detail from one type of graphite to another, and with the direction in which measurements are made. Graphite has a low density (about 2.0) and is comparatively cheap, so that its low temperature limitations (zero ductility at room temperature) may be offset, at least in part, by a re-appraisal of the design factors. It can be joined and fabricated fairly readily, and appears to be a material of great value to advanced high-temperature projects in the future, where composite assemblies of various kinds will be essential.

From author's summary

3595. Jaffee, R. I., and Maykuth, D. J., Refractory materials: Part 1, Technology and low-temperature behavior; Part 2, High-temperature behavior, *Aero/Space Engng.* **19,** 6, 22–27, 48, June 1960; **19,** 7, 39–44, July 1960.

Part I deals with the general technology of refractory materials —that is, their availability, methods of extraction, consolidation to primary shapes, and fabrication to secondary shapes and end items. The stability of the refractory materials (thermodynamic, chemical stability in service environments, and thermal stability after use) is discussed in general terms. The mechanical behavior at low temperatures, particularly the low-temperature brittleness problem, is discussed. In Part II authors discuss mechanical behavior at elevated temperatures and the physical properties important in controlling thermal stresses developed in structural applications. Future trends for these materials are also suggested.

From authors' summary

3596. Warburton, F. L., The dynamic mechanical properties of wool at very low frequencies, *J. Textile Inst., Trans.* **50,** 1, 1–17, Jan. 1959.

The dynamic mechanical properties of wool in extension have been measured over a frequency range extending from 2×10^{-4} to 1.7 c/s, and under three different conditions of temperature and regain. The results so far obtained suggest that increase in temperature has the same effect on the mechanical properties of wool as it has on those of other high polymers and that these effects are almost entirely the result of a plasticizing action. The effect of absorbed moisture appears to be more complex in that, while a plasticizing action is still the largest effect, the actual magnitude of the delayed elastic extension is apparently increased also, although to a much less extent than the reduction in internal friction.

From authors' summary

3597. Kenny, P., and Chaikin, M., Stress-strain-time relationships of non-uniform textile materials, *J. Textile Inst., Trans.* **50,** 1, 18–40, Jan. 1959.

A general relationship has been derived between the extension of, and the load applied to, a specimen of nonuniform cross-sectional area. The behavior of uniform and nonuniform specimens has been compared analytically for a power law relationship between stress and strain, and is shown to differ significantly when the nonuniform specimen was a truncated cone or when the area varied according to the gaussian frequency distribution. The extensions under load of typical, nonuniform keratin fibres have been determined by numerical integration to illustrate a general method which may be used for any cross-sectional area distribution and for any stress-strain relationship.

The creep behavior of nonuniform specimens has been similarly treated, with a brief note on the stress-relaxation of nonuniform specimens and on the effect of nonuniformity on such properties as breaking stress, breaking strain and work to extend.

As an example of the profound effects which may be caused by nonuniformity, a typical keratin fiber, having a coefficient of variation of cross section of 16%, subjected to a particular load, extends 60% more than a uniform fiber having the same average cross-sectional area.

Similar mathematical procedures can be employed not only to study other rheological phenomena of any dimensionally nonuniform material, but also to advance knowledge of the structural irregularities of textile fibers and the mechanical behavior of textile assembles.

From authors' summary

3598. Holden, G., Tensile properties of textile fibres at very high rates of extension, *J. Textile Inst., Trans.* **50,** 41–54, Jan. 1959.

Data are presented on nylon, terylene and cellulose acetate continuous-filament yarns at rates of strain from 0.33% per sec to 66,000% per sec, the high rates being achieved by a ballistic method. The breaking stresses of all the materials investigated are shown to be greatest at the high rates, and the work of rupture of medium-tenacity nylon appears to decrease to a minumum at about 4,000% per sec. The work of rupture of high-tenacity nylon is shown to increase with increased rate of strain, and that of the Terylene and cellulose acetate specimens is shown to remain constant.

From author's summary

3599. Smith, J. C., McCrackin, F. L., and Schiefer, H. F., Characterization of the high-speed impact behavior of textile yarns, *J. Textile Inst., Trans.* **50,** 1, 55–69, Jan. 1959.

This paper discusses how the behavior on impact of textile yarns may be characterized in terms of such parameters as tenacity-strain data, breaking energy density, limiting breaking velocity, and critical velocity. Methods are given for obtaining the parameters from tests involving speeds of impact of 50 m/sec or less. At greater speeds of impact, strain-wave phenomena become appreciable, but the behavior of the yarn may be studied by transverse impact methods. The results of a wave theory for transverse impact are given. The theory is then applied in a method for measuring longitudinal strain-wave velocity, and in two methods for obtaining tenacity-strain curves from high-speed transverse impact tests. From authors' summary

3600. Hearle, J. W. S., El-Behery, H. M. A. E., and Thakur, V. M., The mechanics of twisted yarns: Tensile properties of continuous-filament yarns, *J. Textile Inst., Trans.* **50,** 1, 83–111, Jan. 1959.

The theories of the extension of yarns which have been proposed by Gégauff, Platt, and Hearle and the assumptions on which they are based are considered. Experimental studies of the tensile properties of twisted continuous-filament yarns are reviewed. A range of yarns has been twisted, and their tensile properties determined. Reasons for the variation of stress-strain curves, modulus, limit of proportionality, breaking extension, and tenacity are discussed, and the results compared with theoretical predictions. The effects of processing conditions, and deviations of yarn structure from an idealized model are also mentioned.
From authors' summary

3601. Eeg-Olofsson, T., Some mechanical properties of viscose rayon fabrics, *J. Textile Inst., Trans.* **50,** 1, 112–132, Jan. 1959.

The design of fabrics for special purposes is facilitated if the relations between the deformations of the fabrics under the various types of applied loads are known. In this paper, the concepts used in the subject of applied mechanics and their bearings on fabric structure are developed. New instruments or modifications of existing ones are described. From author's summary

3602. Taylor, H. M., Tensile and tearing strength of cotton cloths, *J. Textile Inst., Trans.* **50,** 1, 161–188, Jan. 1959.

Tensile strength and tearing strength are discussed separately. A relation between cloth tensile strength, yarn strength and the parameters of cloth construction and yarn construction is suggested.

Tearing strength is shown to be dependent mainly on the spacing and strength of the threads being torn and the force required to make them slip over the crossing threads.

Experimental results are given to illustrate the validity of the relations derived from theoretical considerations.
From author's summary

Book—3603. Sinnott, M. J., The solid state, for engineers, New York, John Wiley & Sons, Inc., 1958, xi + 552 pp., $12.50.

This book deals with fundamental principles underlying the behavior of materials in the solid state. It is intended to fill the gap in solid-state literature between current publications dealing with advanced mathematical-physical concepts of the solid state on the one hand, and the superficial handbook-type treatment of solids on the other. Its primary concern therefore is the unification of these hitherto divergent approaches to solid-state phenomena, in terms comprehensible to an engineering audience.

The first five chapters introduce physical and thermodynamic concepts relevant to the micro properties of solids. This is followed by four chapters, each dealing with one of the principal types of crystalline solids. The next three chapters discuss various implications of crystalline structure and bonding, e.g. deformation, crystal imperfection and boundary effects. The remainder of the book is devoted largely to mechanical, thermal, electrical and magnetic application of theory presented earlier, with new concepts introduced as needed.

A book whose mission is to elucidate to an engineering audience, solid-state fundamental phenomena and applications has long been needed. At the level to which this book is directed, it is understandable that much of the theory is presented in an unrigorous fashion and the author has provided many references for the reader with particular interest in specific areas. However, some of the presentation is rather obscure and unnecessarily difficult to follow. There are a large number of typographical and nomenclature inconsistencies. M. L. Baker, USA

Structures: Simple

(See also Revs. 3411, 3488, 3508, 3512, 3515, 3619, 3852, 3916)

3604. Sawczuk, A., Two problems of limit analysis of flat slabs (in Polish), Ksiega Jubileuszowa dla Uczczenia Zaslug Naukowych Prof. Dra Witolda Wierzbickiego, Warszawa, Panstwowe Wydawnictwo Naukowe, 1959; 283–304.

The problem of limit load of a girderless floor is solved on the basis of the theory of plastic flow, assuming that the body is rigid-plastic and the structure of the floor plate layered orthotropic. The Johanson and Coulomb-Tresca yield conditions, as generalized to the case of orthotropic body, are used. The upper limit of the collapse load is determined by the kinematic method; the lower one, by the statical method. The differences between the values obtained are small. They depend on the value of the ratio of the transverse dimensions of the columns and the dimensions of the column network.

In addition the author solves the problem of limit load of a circular girderless floor uniformly loaded. The cases of isotropic, orthotropic, and nonhomogeneous plate are considered.
J. Czulak, Poland

3605. Kaliszky, S., Calculation of the load bearing capacity of concrete and reinforced concrete walls loaded in their own plane (in English), *Acta Techn. Acad. Sci. Hungaricae, Budapest* **28,** 3/4, 441–473, Mar./Apr. 1960.

Rigid-plastic behavior for concrete is assumed with failure (yield) occurring on plane surfaces which crack or crumble at critical normal stresses or slide at a Coulomb critical shear stress ($\tau = c + \sigma \tan \phi$). Rectangular walls loaded through rigid beams along part or all of the top and bottom edges are considered. Failure mechanisms are postulated and the load minimized for one independent parameter; author claims this to be the failure load on basis of minimum theorem of plasticity. A statically admissible lower bound to the failure load is not considered.

Plots of failure load against height-to-breadth ratio of wall for varying amounts of reinforcing steel are given for each loading case.

Reviewer observes that plane strain is tacit in both yield condition and failure mechanisms so that theory is properly applicable only to very thick walls.
J. H. Percy, New Zealand

3606. Brough, J. C., Jr., and Stephens, B. H., Jr., Long span prestressed concrete folded plate roofs, *Proc. Amer. Soc. Civ. Engrs.* **86,** ST 10 (*J. Struct. Div.*), 87–108, Oct. 1960.

3607. Gutzwiller, M. J., and Musleh, F. E., Freezing and thawing effects on prestressed concrete, *Proc. Amer. Soc. Civ. Engrs.* **86,** ST 10 (*J. Struct. Div.*), 109–124, Oct. 1960.

3608. Vasarhelyi, D. D., Taylor, J. C., Vasishth, N. C., and Yuan, C.-Y., Test of a riveted plate girder with a thin web, *Proc. Amer. Soc. Civ. Engrs.* **86,** ST 10 (*J. Struct. Div.*), 23–51, Oct. 1960.

A detailed record of the experimental results obtained from tests on a full-size riveted plate girder with a web plate thinner than that required under the present design specifications is reported.

Both the web-buckling phenomenon and the diagonal-tension phenomenon of the web plate under load were carefully observed. Comparison was then made between the computed buckling loads and the values determined from experimental data. Particular emphasis was laid on the behavior of the web after being loaded beyond the conventionally termed "buckling load," with a view to evaluating the importance of the buckling of the web with respect to practical design. Study was also made on the change in the shear-carrying behavior of the web after buckling occurred and on the ability of the web to withstand loads in excess of the buckling value. From authors' summary

3609. Bannister, A., Characteristics of symmetrical segmental members, *Concrete Constr. Engng.* **55,** 7, 257–262, July 1960.

3610. Hondros, G., and Marsh, J. G., Load distribution in composite girder-slab systems, *Proc. Amer. Soc. Civ. Engrs.* **86,** ST 11 (*J. Struct. Div.*), 79–109, Nov. 1960.

3611. Schmidt, K., On the strength behaviour of composite structural elements (in German), *ZVDI* **102,** 20, 829–840, July 1960.

3612. Rosman, R., Stress analysis of horizontally loaded shear walls of tall buildings (in German), *Bauingenieur* **35,** 4, 133–136, April 1960.

Paper investigates elastic stresses in sheer walls with one or two vertical rows of rectangular window openings. For purpose of analysis, structure is subdivided into vertical strips (corresponding to the solid wall between windows) connected by vertical "joining strips" the elastic properties of which are such as to represent the flexibility of the horizontal connecting beams. Vertical shearing force in the joining strip is the unknown function for which a differential equation is formulated. Solution by Galerkin's method is presented. O. Hoffman, USA

Book—3613. Guldan, R., Rigid frames and continuous beams, [Rahmentragwerke und Durchlauftrager], 6th enlarged ed., Wien, Springer-Verlag, 1959, xxiii + 501 pp. $20.

Previous editions (reprints of the 2nd) were well-appreciated for their thorough, lucid, and practical approach to the analysis of continuous structures, the main line of attack being the displacement method, with fixed-point method and moment distribution thrown in chiefly as supplementary approaches. Wealth of numerical examples and of time-saving auxiliary tables has been a distinguishing feature of this work since its appearance.

The new edition includes in First Section (Theoretical part) a new chapter on the general classification of framed structures; some methods have been simplified like those for the treatment of frames containing hinged connections and of symmetrical frames with symmetric and unsymmetric loading; another addition concerns application of displacement method to cases of frames containing hinged connections and liable to vertical joint displacements; also, derivation and tabulation of ready-to-use equations for analysis of the more important frame shapes has been implemented.

In Second Section (Applications), the number of examples has been increased considerably and treatment broadened and partly simplified. A welcome innovation is inclusion of 10 cases treated also in author's work on moment distribution ["Die Cross Methode und ihre praktische Anwendung, Springer, 1955 is AMR 9(1956), Rev. 3577], thus facilitating comparison of the two approaches. (Comparison has been further facilitated by unifying notations in relevant chapter of First Section.)

Last Section (Numerical and graphical tables) has also been enlarged considerably, mainly by values for members hinged at one end and for members haunched and loaded symmetrically; also included now are tables of carry-over factors for members with symmetrical and unilateral straight and parabolic haunches.

Otherwise, new edition follows mainly the previous ones, the main headings of the theoretical section being: Frames without haunches, Frames with freely variable cross section, Influence lines for statically undetermined structures, Effects of temperature changes, The continuous beam of variable cross section with due regard to all special cases, Practical methods for the solution of systems of linear equations, Simplified analysis of structures with a high degree of statical indeterminacy, and Various methods and approximation techniques for frame analysis.

A very useful book in the hands of designing engineers.

C. H. Lerchenthal, Israel

3614. Lee, S. L., and Ball, R. E., Analysis of braced frames by relaxation method, *Struct. Engr.* **38,** 11, 346–352, Nov. 1960.

3615. Neal, B. G., Deflections of plane frames at the point of collapse, *Struct. Engr.* **38,** 7, 224–229, July 1960.

Utilizing the plastic hinge approach, a clamped beam and a clamped rectangular portal frame were analyzed to show that substantial support flexibility may have relatively little influence upon the structural deflections at incipient collapse. Limitations are indicated for these flexibilities. Utilization of this approach is indicated for estimation of sinking and spreading of portal frame column bases. H. Becker, USA

3616. Filho, F. V., Matrix analysis of plane rigid frames, *Proc. Amer. Soc. Civ. Engrs.* **86,** ST 7 (*J. Struct. Div.*), 95–108, July 1960.

Considering plane rigid frames, author formulates in matrix form the relations between the internal forces, external loads and the displacements (including rotations) of the joints in accordance with the ordinary assumptions of the elastic theory of structures. The equilibrium equations are derived from the principle of virtual work, also in matrix form, with either displacements or forces as unknowns. The final equations obtained are in terms of the forces at the ends of each bar.

A few simple examples are presented for which solutions can also easily be obtained by the ordinary methods of the analysis of structures. It is presumably only for complicated examples that the present formulation manifests its advantage, especially when a digital computer is employed. Z. Kami, Israel

3617. Heyman, J., On the minimum-weight design of a simple portal frame, *Inter. J. Mech. Sci.* **1,** 1, 121–134, Jan. 1960.

Author extends the analysis of Foulkes [AMR 8(1955), Rev. 75], which employs a plastic collapse theory for minimum-weight design, to (a) frames with unequal columns and (b) frames with tapered members. Results for the latter are called "absolute minimum-weight design," and show a large weight saving over prismatic-member frames in three simple examples. A practical method of approximating absolute minimum-weight design is also given. A. D. Topping, USA

3618. Bycroft, G. N., Effect of stiffness taper in aseismic design, *Bull. Seismol. Soc. Amer.* **50,** 4, 537–552, Oct. 1960.

Paper is divided into two parts. In first an analytical investigation of a continuous shear beam with linearly varying stiffness and constant mass subjected to a continuous white noise support acceleration is made assuming constant factors of critical damping for each mode and well separated natural frequencies. Root-mean-square strains are obtained as a function of a stiffness distribution parameter. Second part consists of an analog computer investigation of response of lumped building frames to successive bursts of white noise excitation. Author finds that variation of mean largest strain due to a series of bursts with stiffness distribution parameter may be approximated by that of rms strain and that probability of strains larger than twice mean largest is very small. F. L. DiMaggio, USA

Structures: Composite

(See also Revs. 3414, 3509, 3511, 3531, 3533, 3916)

Book—3619. Leliavsky, S., Irrigation and hydraulic design, Vol. 3, New York, London, The Macmillan Co., Chapman & Hall, Ltd. 1960, xvi + 765 pp. 13 guineas = $38.22.

Volume, subtitled "Hydraulic structures for irrigation and other purposes", concludes the great trilogy on hydraulic engineering [Vol. 1 reviewed in AMR 9(1956), Rev. 777; Vol. 2 in AMR 11(1958), Rev. 1657]. This volume contains diversion headworks—cofferdams; ship locks; arch bridges; dams—gravitational, arch, buttress; electrification of irrigation works. Several chapters incorporate previous well-known papers by author, in the U.S. and Great Britain technical press: economic comparison of various solutions; modern dewatering methods in irrigation problems; gravity dam deflections; uplift in gravity dams; stresses and temperature effects in dams; modern tendencies in arch dam design; Baroque tendencies in the evolution of gravity dam type, buttress dams and hollow dams. Similarly to previous volumes, detailed examples with all computations and drawings are presented. Some items are unique, as the heightening of existing dams, based on the practice of Aswan Dam in Egypt. Chapter on electrification is a rather concise treatment of water turbines, aimed at civil engineers for selection of principal dimensions of hydraulic machinery and foundation for an outlet.

Hydraulic engineers will find in this great trilogy many interesting details from the practice in Egypt and in Western Europe, partly in Russia. The misspelling of several names, like Francius instead of Franzius, Luden instead of Ludin, Keo Kuk instead of Keokuk, should be improved in second impression.

S. Kolupaila, USA

3620. Serafim, J. L., General critical analysis of the most important methods for the computation of arch dams (in Portuguese), Lab. Nac. Engen. Civ., Lisboa Mem. 126, 21 pp., 1958.

The evolution of methods of computation of arch dams, connected with the great achievments in this field, is presented. It is shown that the smaller the number of internal forces in the faces of an element which are neglected, the greater the accuracy of the methods.... The two ways used nowadays in the analytical computation of dams are described. These methods are based on the shell theories and methods of division of the hydrostatic load between the arches and the cantilevers of the "tiral-load" type. The most important papers on these two methods are analyzed. The use of systems of equations instead of trials for the division of the hydrostatic load is discussed. Finally, a method based directly on the general equations of the theory of elasticity solved through relaxation for the case of a cylindrical arch dam is briefly described. In the text the use of models is suggested as the most dependable method.

From author's summary by I. Wolff, Brazil

3621. Antipov, A. I., Problem of selecting a rational underground contour of concrete dams on sand foundations (in Russian), *Gidrotekh. Stroit.* **29,** 10, 36–40, Oct. 1959.

By determining the proportions of the main dimensions of a low gravity dam and the length of both the horizontal apron and of the rubble core wall, these dimensions may be computed from the condition of stability against sliding. These proportions were determined in accordance with well-tried values and, what is of particular value, for the most economical solutions. The process is illustrated on two examples: one without, the other with, drains in the base. The purpose of the solution is to make possible a rapid selection from several variations. For a final design it is necessary to check the dimensions by means of precise static solution.

V. Mencl, Czechoslovakia

3622. MacNeal, R. H., Arch dam analysis with an electric analog computer, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 4 (*J. Engng. Mech. Div.*), 127–151, Aug. 1960.

An electrical analogy that simulates the elastic deformations of arch dams is described herein. This analogy consists of resistors, transformers, and current generators. The results of an analog computer analysis of a dam are compared with field measurements. The results of a design study of another dam are summarized.

From author's summary

3623. Sokolov, A. G., Calculations for flanged joints (in Russian), Information regarding steel constructions, Vol. 2, Moscow, 1958, 131–155; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10947.

Using a calculation procedure, determinations are made of the moments in a flange welded to a thin-walled tube and loaded with an axial tensioning load evenly distributed around the bolts. The flange is investigated as a circular plate; the mutual deformation of flange and tube is calculated. An experimental investigation is made to determine the carrying capacity of the tubes with flanges of different dimensions, when being subjected to axial compression. The comparison of the calculation and experimental data may be taken to be acceptable since the author in his calculation determined the carrying capacity on the assumption of the onset of the limit of yield in the most stressed point with unbounded elasticity for the material. There was definite divergence in the results of the experimental and theoretical work. The carrying capacity for similar components should be determined on the basis of the theory of plasticity. V. S. Zhukovskii

Courtesy Referativnyi Zhurnal, USSR

3624. Troughton, A. J., Relationship between theory and practice in aircraft structural problems, *J. Roy. Aero. Soc.* **64,** 599, 653–667, Nov. 1960.

Paper describes the relative merits of stressing and testing in aircraft structural design from all aspects, including the relationship between theory and practice.

From author's summary

3625. Sandorff, P. E., Structures considerations in design for space boosters, *ARS J.* **30,** 11, 999–1008, Nov. 1960.

Paper describes ways in which structures problems influence and are influenced by the other aspects of early space vehicle design. The nature of the major loading conditions and how they may vary with vehicle size, configuration and design parameters is discussed. Structural design methods available to support the major vehicle loads are compared, using structural indexes to assess future design problems. Functional components of the structure are analyzed to determine how weight may vary with vehicle design parameters. Dead weight data available on existent designs are summarized, and the trends noted. In support of the predictions derived analytically, a family of large booster vehicle designs is presented. S. Lampert, USA

3626. Sharman, P. W., Approximate bending moment diagrams for flight maneuvers, *J. Aero/Space Sci.* **26,** 8, 530–532 (Readers' Forum), Aug. 1959.

A method for quickly determining the approximate bending-moment diagram for a body of typical missile configuration is presented. Author assumes a small number of uniformly distributed loads instead of several discrete loads. Bending-moment equations (based on assumed distributions of lift and weight) are derived for both steady-state and transient maneuvers.

A comparison between this method and the standard one based on 18-element discrete loading shows good agreement.

D. W. Rhoads, USA

3627. Sizov, B. G., A diagram to give an approximate assessment of the deflection moments in the hull of a ship (in Russian), *Sudostroenie* no. 9, 15–19, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 10813.

The author proposes (for the purpose of changes of loading in the acceptable practical conditions required) to investigate a supplementary deflection moment ΔM as a geometrical surface $\Delta M = M(x, x_1)$. He bases his decision on the known expression for the above moment which appears in any section (with abscissa x_1) of the hull of a ship when it is approached in another arbitrary section (with abscissa x) by a unit load P_x. The dissection of a surface of this nature into planes $x - x_1$ results in curves of equal value for the auxiliary deflection moments, while the projection of these curves onto one surface gives the proposed diagram for the changes of the deflection moments. V. P. Belkin

Courtesy Referativnyi Zhurnal, USSR

3628. Hoffman, G. A., Optimum tolerances of sheet materials for flight vehicles, *ASME Trans.* **82** B (*J. Engng. Industry*), 4, 363–368, Nov. 1960.

A method is derived for specifying economically optimum tolerances for a variety of sheet materials for use in flight vehicles. The results indicate a significant disparity between present industry practices and the apparent optimum tolerances. These tolerances are listed as possible target requirements for rolling programs of new and future metals.

From author's summary

Machine Elements and Machine Design

(See also Revs. 3415, 3416, 3417, 3942, 3949, 3950)

3629. Durant, N. J., Stress in a dynamically loaded helical spring, *Quart. J. Mech. Appl. Math.* **13,** 2, 251–256, May 1960.

The axial motion of a spring fixed at one end with an attached mass at the other caused by a time-varying force at the end is considered. The spring is treated approximately as a uniform elastic rod. The governing differential equation for this model is the one-dimensional wave equation which is solved and the appropriate end conditions satisfied by use of the Laplace transform. A numerical example corresponding to a spring in a swash plate pump is included. In an appendix the author uses his more exact theory to show that the first-order correction to the lower frequency of free vibration given by the elementary theory which neglects the mass of the spring can be obtained by using an effective mass equal to the mass of the attachment plus 1/3 the mass of the spring in the elementary formula for the frequency. However, reviewer believes that this same correction should not be used in the more exact theory and that, therefore, the author's illustrative example is in error. M. W. Johnson, Jr., USA

3630. Hain, K., Spring mechanisms, force analysis: Part 1, *Prod. Engng.* **32,** 1, 26–28, Jan. 1960.

3631. Erisman, R. J., Dimensionless parameters for helical compression springs, *ASME Trans.* **82** B (*J. Engng. Industry*), 4, 439–443, Nov. 1960.

Spring design, in many instances, is still a trial-and-error process. The underlying reason is the large number of complex variables which must be related to the allotted space which the spring will occupy and to the desired loads throughout the working range. This paper presents a system of parameters which enables the spring designer to graphically portray these variables for a given problem. Derivations are based on the total number of coils as well as the outside diameter which accurately defines the entire space required for the spring. Charts are presented for springs with two dead coils and a torsion modulus of 11,500,000 psi.

From author's summary

3632. Exline, P. G., Bourdon tube deflection characteristics, *ASME Trans.* **82** D (*J. Basic Engng.*), 4, 887–893, Dec. 1960.

Test results and an analysis of the deflections of 50 Bourdon tubes are reported. Parameters are established for preliminary design purposes and causes of scatter and inconsistencies in the data are discussed. Measurements were made of changes in the radius of curvature of the tube and of the change in slope of the free end. Results are reduced to dimensionless parameters. Response as a function of pressure was determined to be linear. Proposals are set forth for the manufacture of tubes of special cross sections for future tests. C. E. Balleisen, USA

3633. Tokunaga, H., On the roller straightener: Part 1, Straightening of sections, *Bull. JSME* **3,** 12, 572–579, Nov. 1960.

The mechanism of straightening of sections and rails by means of a roller straightener with axial adjustable rolls has not been clarified. The author studied this problem analytically and derived the relations between the largest radii of bending necessary for straightening, at the points of the second and third rolls of straightener and the results of straightening, when the modulus of elasticity and curvature of sections before operating are known.

The author also shows, as a special case, that the sections can be straightened not only in horizontal plane, but also vertical plane in accordance with severe bending in even horizontal plane by the straightener rolls.

The present paper deals with the repeated bending tests and the tension-compression tests for specimens of hard steel and brass, as these characteristics of repeated cold works on these materials are the most important points for designing the straightening machine. From author's summary

3634. Spear, G. M., King, C. B., and Baxter, M. L., Jr., Helixform bevel and hypoid gears, *ASME Trans.* **82** B (*J. Engng. Industry*), 3, 179–190, Aug. 1960.

The Helixform process is a recent development in the art of gear cutting. Gears made by this method are classified as nongenerated, which means that the workpiece remains at rest while the teeth are being cut. Cutting the gear without generation is a process especially adapted to high production and accurate machining and is the method used to manufacture most automotive spiral bevel and hypoid gears. Pinions which match nongenerated gears are of course produced with generating motion, that is, the tools cutting the teeth of the pinion are mounted on a machine element which, while the teeth are being cut, turns in concord with the turning of the pinion on its axis. From authors' summary

3635. Wellauer, E. J., An analysis of factors used for strength rating helical gears, *ASME Trans.* **82** B (*J. Engng. Industry*), 3, 205–212, Aug. 1960.

This paper discusses the factors used to rate the strength of helical-gear teeth by means of the fundamental tooth-strength formula. The new approach combines different concepts of geometry factors, an improved evaluation of dynamic loads, rational allowable stresses, and risk or reliability considered as a statistical probability. In addition, the inclusion of the effect of operating error and load-distributing tooth flexibility provides the gear engineer with a more accurate means for helical-gear strength rating.

From author's summary

3636. Yakobi, A. M., Calculation of the differential balance of horological movements (in Russian), *Priborostroenie* no. 3, 20-22, 1958; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3548.

A calculation is made of the temperature coefficient of the change in the moment of inertia of a Volet differential balance consisting of a monometallic rim with loading weights and a crossbar, in a first approximation to the change in temperature the coefficient of thermal expansion of the rim being assumed to be greater than that of the crossbar. With the accuracy indicated, an expression is found for the elastic line of the rim, and the components of the temperature coefficient of the balance wheel are determined by the influence of the arrangement of the loading weights in the deformation of the rim of the balance wheel, and the deformation of the wheel rim and the coil spring. The expressions obtained enable the arrangement of the loading weights at which the temperature coefficient of the balance wheel is zero to be determined with greater accuracy than hitherto possible.

A. S. Alekseev

Courtesy Referativnyi Zhurnal, USSR

3637. Rouverol, W. S., Inertial effects in a multiple-ball transmission, *ASME Trans.* **82** B (*J. Engng. Industry*), 4, 399-406, Nov. 1960.

A new type of mechanical variable-speed transmission, which owes its improved efficiency and wear-life to the utilization of multiple point contacts in pure rolling, has a power capacity in proportion to the maximum tractive forces and rolling velocities developed by a large number of small steel balls. Designing for maximum power capacity depends on finding the point at which the components of tractive force arising from inertial effects at high speed become so large as to interfere with the proper kinematic action of the balls. Consideration is given to the influence of a number of design and operating parameters, such as ball diameter, cage diameter, cage velocities, and velocity ratio.

From author's summary

3638. Denil, M. J., The application of nomography to the design of a two-piece propeller shaft system, *GM Engng. J.* **7**, 4, 2-10, Oct./Nov./Dec. 1960.

The design of a two-piece propeller shaft system is developed during the early design stages of the car frame and underbody. In many cases, propeller-shaft-system designs must be developed almost daily to meet new requirements imposed by changes in the still-flexible design of the frame and underbody. To decrease the time involved in developing an optimum design for a propeller shaft system, Cadillac Motor Car Division engineers applied nomography to replace the previously used method of making a full-size layout for each proposed system. The nomograms developed save valuable time in the repetitive solution of the equations required to determine the forces acting on the system at a specific design position of the rear axle. In addition, modifications to an original design can be made directly on the nomograms, which provide the designer with a closer insight into the interrelationship between the design variables.

From author's summary

3639. Glushchenko, I. P., and Nikol'skii, V. K., The dynamics of a system of two masses with a non-linear linkage (in Russian), Some problems of the dynamics of machines, L'vov, In-ta, 1956, 17-30; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3474.

The problem is investigated of the rectilinear motion of two point masses joined by a ponderous, flexible, inextensible filament, under the action of external forces of constant magnitude and direction. It is assumed that the displacement of one of the masses is restricted in direction. Two stages of motion are distinguished. In the first stage, only one of the masses moves. In the second stage, the connecting filament sets the second mass in motion. The problem is then reduced to a system of two nonlinear equations:

$$m_1\ddot{x}_1'' + zC_n = P_1, \quad m_2\ddot{x}_2'' - zC_n = P_2$$

In the above:

$$z = b + x_1 - x_2, \quad C_n = 0.204\, q\, \sqrt{\frac{z}{S-z}}$$

C_n is the reduced rigidity of the filament, S the length of the filament. An approximate analysis of the motion is made for particular cases.

E. N. Berezkin

Courtesy Referativnyi Zhurnal, USSR

Fastening and Joining Methods

(See also Rev. 3623)

3640. Ito, K., Note on adhesive strength test by lap joint, *Scient. Pap. Inst. Phys. Chem. Res., Tokyo* **54**, 3, 295-306, Sept. 1960.

Lap joint as a typical specimen for the strength test of welding joint or adhesive joint was analyzed by elasticity theory under various boundary conditions in tension. Numerical calculations in these results were performed for some examples. The boundary conditions and the dimensions of joint specimen greatly influence the analytical results, in particular the stress concentration factor at corner section which determines the rupture of specimen, and therefore should be specified definitely in the strength test of adhesive joint or welding joint. Complicated types of lap joint were analyzed theoretically as an appendix.

From author's summary

3641. Matting, A., Feasibilities of metal glueing (in German), *Z. Flugwiss* **8**, 6, 153-161, June 1960.

Thermochemical "Setting" mechanism of plastic adhesives is considered and graphs for time-temperature relations of setting process are given for two vinyl and metacoyl adhesives commercially available in Germany under trade names Agomet E and Metallon K. Data on usability time after mixing are included. Cooling by keeping mixture in iced water increases usability time fourfold. Maximum shear strength determined by testing lap joints is found for 100μ thick layers. Ultrasonics increase strength only slightly. Cold-setting adhesives seem less sensitive to thickness variation than hot-setting types. Results for tensile shear strength depend on relation between setting temperature and testing temperature. If testing temperature is below setting temperature strength is increased. This effect is attributed to thermal stresses due to differences in coefficients of expansion between metal and adhesive. Failure always occurs within body of adhesive and not between adhesive and metal.

Properties of adhesion are time-dependent and stress-dependent. Increasing time and stress results in decreasing modulus of elasticity. Importance of activation energy as result of surface treatment in relation to adhesion strength is considered.

R. Weck, England

3642. Archer, G. R., Calculations for temperature response in spot welds, *Welding J.* **39,** 8, 327-S–330-S (Res. Suppl.), Aug. 1960.

The nature of temperature response in spot welding has an important bearing upon the techniques used for control. The intention of these calculations is to provide insight into the response of the material. This type of calculation shows how the frequency, level and phase control of the power source affects temperature response for single-phase welding. The calculation also shows how the thickness and thermal characteristics of individual alloys will affect the temperature response.

From author's summary

3643. Graham, J. D., Sherbourne, A. N., Khabbaz, R. N., and Jenson, C. D., Welded interior beam-to-column connections, American Institute of Steel Construction (A.I.A. File no. 13-C), 39 pp., 1959.

Rheology

(See Revs. 3470, 3479)

Hydraulics

(See also Revs. 3534, 3658, 3664, 3740, 3742, 3747, 3900, 3901, 3903, 3909, 3920, 3921)

Book—3644. Loncastre, A., Manual of general hydraulics [Manuel d'hydraulique generale], Paris, Eyrolles, 1961, 411 pp. 38. NF.

French edition of the Portuguese "Manual de hidraulica geral" is a concise review of fluid mechanics accompanied by numerical and graphical tables for practical application. Text covers properties of fluids, hydrostatics, general principles and formulas of hydraulics, dimensional analysis, steady flow in conduits, uniform and nonuniform flow in open channels, flow through orifices and over weirs, hydrometric measurements, pump installations. One half of the book contains tables, diagrams and nomograms, and ends with a polyglot dictionary of terms in 6 languages (French, Portuguese, Spanish, Italian, English, German). A very useful manual for hydraulic engineers using metric system and a good example for a similar edition very needed for English units.

S. Kolupaila, USA

3645. Taraimovich, I. I., Specific discharges on spillway and apron (in Russian), *Gidrotekh. Stroit.* **27,** 5, 22–26, May 1958.

Mr. Taraimovich is of the opinion that, up to the present, there is no definite policy in the selection of the proper specific discharge in the design of hydraulic structures (he refers to Soviet design). Analyzing 25 hydraulic structures built on flat land or in rocky mountainous countries, author concludes that the design velocities and actual velocities are different; therefore, in many cases, the design formulas and methods were not satisfactory and resulted in hydrodynamical destruction of spillways or aprons or both. For these 25 dams the author has enumerated, in tabular form, different geological and physico-dynamical factors (parameters) which compose the design. Some of these dams have "undergone" changes due to poor design (i.e. fail).

In conclusion it is suggested that the selection of specific discharges must be made more carefully: by more detailed studies, by applying different methods and selecting one which gives the best service.

N. V. Feodoroff, USA

3646. Gerber, C-S., Height of percolation and dimension of the permeable material in a dam with vertical walls (in French), *C. R. Acad. Sci. Paris* **251,** 6, 849–851, Aug. 1960.

3647. Thirriot, C., Study of the curves of turbulent movement in circular cylindrical galleries (in French), *C. R. Acad. Sci. Paris* **250,** 26, 4283–4285, June 1960.

Book—3648. Zegzhda, A. P., Hydraulic losses by friction in channels and pipelines (in Russian), Moscow, Gosstroiizdat, 1957, 278 pp. + illus.; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3828.

Chap. 1: The present situation of the problem in principle, from literary sources (pp. 9–121). The application of the similarity principle to the problem of the steady flow of a liquid in channels and pipelines is demonstrated, and the relationships are stated for the velocity distribution in channels and pipelines, and for the resistance in the case of turbulent flow of the liquid in "smooth" pressure pipelines. Following Nikuradze's researches, the influence of roughness on the flow resistance of liquids is investigated. From the researches of K. K. Fedyayersky, F. A. Shevelev, N. N. Fomina, Fage, and others, as well as Colebrooke and White, and the Tbilissi Scientific Research Establishment of Hydraulic Engineering, the influence of local, inhomogeneous roughness and other factors on the flow resistance of liquids in channels and pipelines is investigated. Separate consideration is given to the experimental work of G. A. Murin and F. A. Shevelev on the flow resistance of liquids in steel pipes.

Chap. 2.: Uniform motion of a liquid in an open channel (pp. 121–183). General information is given on experimental equipment and the conduct of tests, as practised in the Hydraulic Engineering Laboratory of the Technical College of Engineering Construction (formerly the Hydroelectric Plant Laboratory of the VNIIG), in a flume with artifically roughened bottom and sides. The results of these experiments are discussed and some experimental results contained in the literature, on flow resistance in open channels, are analyzed; from which the appropriate conclusions are drawn. In the most general case (for a flow with and without a pressure head), the coefficient of resistance λ (or the Chézy coefficient C) must, in the author's opinion, depend only on the Reynolds number and a series of nondimensional, geometrical characteristics of the form of the flow cross section, including iregularities in the walls of the channel. The conclusion that the coefficient of resistance is influenced by the slope of the bottom of the channel is not proved clearly for the case of an open channel, by the results of accurate experiments. The character of the cross section of the flow can be determined with sufficient accuracy for engineering calculations from the indicated relationships applying the hydraulic radius and terms for the Reynolds number and the coefficient of resistance. Surface roughness can be quite legitimately allowed for on the basis of the mean height of the protuberances, their spacing, and several other factors, evaluating their influence on the flow resistance statistically. In consideration of the multiplicity of different possible forms of flow cross section, it is recommended when solving practical problems to use an additional coefficient, applying the relationship $\lambda = \psi \lambda_f$, where λ_f is the coefficient of frictional resistance of a smooth or homogeneously rough surface.

Chap. 3. Suggestions for calculating aqueducts or conduits of different types (pp. 183–273). From an analysis of the experimental data of numerous research workers the author suggests that concrete surfaces of channels and conduits should be referred to the surfaces with "granular" roughness and to classify them in the following six categories: A. Exceptionally smooth concrete surfaces, faced with cement plaster and reinforced; expansion joints and other seams worked flush with the surface. B. Concrete surfaces cast in lubricated steel molds, with carefully smoothed or pointed seams and joints. C. Ordinary concrete surfaces, faced with cement plaster and rubbed down. D. Concrete surfaces cast in wooden shuttering, not faced nor rough-faced. E. Built-up (of short links) concrete pipes of small diameter, without special facing of butt joints. F. Surfaces of unfaced, roughly-made, concrete

conduits, or the concrete inner surfaces of pipes of small diameter, not carefully laid. In accordance with this grading, the following mean values of the absolute surface roughness are recommended for use in calculations: 0.30, 0.50, 1.15, 1.15, 2.50 and 4.30 (in mm). For water conduits faced with gunite (pneumatic mortar) the recommended value of the absolute surface roughness is from 3 to 10 for untreated, and 0.5 to 1.5 for smooth-finished, surfaces. For the calculations, Pavlovsky's formula is recommended: $C = r^y/n$ (r = hydraulic radius). The values of the coefficients y and n are given in Table 40 of the book for the above six grades of surface finish, and for different, limiting flow velocities. These have been determined on the assumption that the value of C calculated by the Pavlovsky formula differs from that calculated by the formula for granular surface roughness by not more than ±3-5%. Brick-faced water conduits are recommended to be calculated for an assumed, absolute surface roughness within the limits of 1-3 mm. Wooden pressure pipelines should be calculated by the Blasius equation for $R < 10^5$, and Nikuradze's formula for $R > 10^5$, in the case of smooth tubes, introducing an auxiliary coefficient ψ, of 1.3 or 1.7, depending on the quality of the inner surface of the staves. Open wooden flumes should also be calculated by these formulas for a limiting value of $R_r = 2.5 \times 10^4$, using a coefficient ψ for open channels and flumes, between 1.0 and 1.70 depending on the surface condition; of 1.40 to 2.0, depending on the length of service of the channel, its workmanship, and the presence of any bends in the plan view. Metal (steel or iron) pipelines are classified by the author into five groups, depending on the quality of the seams and the nature of the rivetted joints. Separate equations are suggested for calculating each group of pipelines (for the coefficient of resistance λ, the coefficients ψ and n; or, correspondingly, the numerical values of y and n in the Pavlovsky formula).

V. I. Gotovtsev

Courtesy Referativnyi Zhurnal, USSR

3649. Netsch, H., Calculation of pressure transients in pipes by means of the Laplace transform *(in German), Öst. Ingenieur Z.* **2,** 8, 285-290, Aug. 1959.

An outline study is made of the propagation of pressure waves along a discharging liquid conduit on assumptions which yield a simple wave equation. A single propagation velocity depending on the elastic properties of the liquid and of the conduit wall is assumed. Several examples relating to the closing of valves are investigated by standard Laplace transform methods. These are extended to include a linear frictional resistance to the flow.

A. F. Pillow, Canada

3650. Rouse, H., Distribution of energy in regions of separation, Introduction; Continuation and end (in English and French), *Houille Blanche* **15,** 3, 235-246, May 1960; **15,** 4, 404-411, June 1960.

Paper gives a clear synthesis of mean-flow analyses common in hydraulics, and analyses of turbulent flow developed in other branches of fluid mechanics for special cases.

The synthesis is applied on the determination of the mean and secondary flow patterns in two comparable boundary configurations, viz. the axisymmetric flow in an abrupt pipe inlet and around a blunt shaft.

Theory underlying the evaluation of experiments is given as a thorough analysis of equations of momentum and of energy for mean and secondary motion. Also pertinent features known in theory of turbulence are stated [cf. AMR **9**(1956), Rev. 4000 and AMR **13**(1960), Rev. 1879].

On basis of theory, measurements have been analyzed and adjusted and have been presented in the form of flow patterns, curves of variation of the individual momentum and energy terms throughout regions of separation.

The analysis of the results contains a valuable discussion on the turbulence production, transport and dissipation and on the influence of turbulence on the mean-flow pattern. Author shows what is still hypothesis and what is established by direct measurement.

The experiments are described with a critical review of the possible instrumental errors.

H. J. Schoemaker, Holland

3651. Camichel, C., Variations of a whirlpool (in French), *C. R. Acad. Sci. Paris* **250,** 20, 3247-3251, May 1960.

3652. Chartier, C., Bigaud, A., and Bureste, H., On the hydrodynamic flow downstream of a cylinder (in French), *C. R. Acad. Sci. Paris* **251,** 4, 507-508, July 1960.

3653. Johnson, V. E., Jr., and Rasnick, T. A., The drag coefficient of parabolic bodies of revolution operating at zero cavitation number and zero angle of yaw, NASA TR T-86, 27 pp., 1961.

Object of paper was to determine, theoretically and experimentally, magnitude of form-drag coefficient of paraboloid bodies of finite fineness ratio (experiments limited to fineness ratios 1.00 and 3.33) for zero yaw and zero base cavity pressure coefficient. Theory involves assumptions that cavity shape is nearly elliptical and that drag coefficient at finite cavitation number (i.e. the negative of cavity pressure coefficient) is the sum of the drag coefficient at zero cavitation number and the cavitation number. It is noted these assumptions limit theory to thin bodies. Analysis used to determine drag coefficient at zero cavitation number is based on work of Rouse and McNown [State Univ. Iowa Bull. 32, 1948].

Experiments were conducted in high-speed towing tank at 14-inch submergence and velocities from 130 to 190 fps. Sting interference on cavity shape was considered negligible and form drag found by subtracting skin-friction drag from total measured drag. Skin friction was computed as for flat plate of same length and surface area with turbulent boundary layer; it amounted to about 4% of total drag for fineness ratio unity and about 40% of total drag for fineness ratio 3.33. Cavity pressure was measured and form drag coefficient for zero cavitation number obtained by subtracting cavitation number from form drag coefficient. Drag coefficient thus obtained was independent of speed.

Although direct comparison between theory and experiment is only valid for the finer body, excellent agreement was obtained for both. Measured surface pressure coefficients also were in very close agreement with computed values.

In relation to work of Armstrong [Armament Res. Establishment Rep. 21/54, August 1954] present study shows form drag coefficient of paraboloids to be about one half that of cones having same fineness ratio.

Reviewer notes this paper should be coupled with that of Christopher and Johnson [NASA TN D-436, Aug. 1960].

R. A. A. Bryant, Australia

3654. Plesset, M. S., On cathodic protection in cavitation damage, *ASME Trans.* **82** D (*J. Basic Engng.*), 4, 808-820, Dec. 1960.

Using experimental techniques author shows that cathodic protection can reduce cavitation damage if cathodic currents are sufficiently high to produce a gas layer on the specimen surface. Increasing rates of gas evolution or cathodic current increase the cushioning effects and decrease the cavitation weight losses.

J. S. Marcus, USA

3655. Beaufrere, J., Experimental study of the scale factor in the cavitation of hydraulic turbines (in French), *C. R. Acad. Sci. Paris* **250,** 22, 3576-3578, May 1960.

3656. Beaufrere, J., Study of the scale factor in cavitation tests in hydraulic turbines (in French), *C. R. Acad. Sci. Paris* **250,** 15, 2677–2679, Apr. 1960.

3657. Brackenridge, J. B., Transverse oscillations of a liquid jet: Part 1, *J. Acoust. Soc. Amer.* **32,** 10, 1237–1242, Oct. 1960.

Observations have been made of a thin rectangular jet which issues from an orifice and impinges upon the apex of a rigid wedge which is parallel to the plane of the jet. Such a system displays steady motion or motion corresponding to one of a unique set of ordered oscillatory modes. Which state of motion occurs at a given time depends upon stream thickness, orifice-to-edge distance, stream velocity, kinematic viscosity, and the previous history of the jet. The investigation is divided into two main parts. One deals with the ranges of parameters of the system for which it will execute self-maintained oscillations of a given mode; the other treats frequency characteristics for the different modes. It is found that self-maintained oscillations exist in fluids with a wide range of viscosity. The frequency characteristics are obtained by both optical and acoustical methods; an empirical formula for the frequency is developed. From author's summary

Incompressible Flow

(See also Revs. 3650, 3652, 3653, 3654, 3698, 3718, 3720, 3724, 3731, 3737, 3738, 3740, 3747, 3794, 3797, 3809, 3821, 3907, 3910, 3911, 3943)

3658. Han, L. S., Hydrodynamic entrance lengths for incompressible laminar flow in rectangular ducts, *ASME Trans.* **82** E (*J. Appl. Mech.*), 3, 403–409, Sept. 1960.

By linearizing the Navier-Stokes equation a solution is given for the incompressible laminar flow in the entrance region of rectangular ducts of arbitrary aspect ratio. Numerical results of the velocity distribution, pressure drop and entrance length are presented for six different aspect ratios of the duct. The entrance length parameter $l_e/d_e Re$ (l_e = entrance length, d_e hydraulic diameter of the duct, Re Reynolds number) rises from 0.0099 for zero aspect ratio (two parallel plates) to 0.0752 for unit aspect ratio (square cross section). The additional pressure drop in the entrance against the fully developed duct flow increases also with the aspect ratio. Some available experimental and theoretical data are compared with the results of the present paper.

N. Scholz, Germany

3659. Case, K. M., Stability of inviscid plane Couette flow, *Physics of Fluids* **3,** 2, 143–148, Mar./Apr. 1960.

Author investigates general solution of equation of small disturbances to plane Couette flow at infinite Reynolds number R and has brought to light certain new mathematical solutions. Whether these are physically significant, that is proper limits (as R tends to infinity) of solutions at finite R, is an open question awaiting further study.

In reviewer's opinion, criticism of earlier workers, implied by tone of article, is not called for. N. Curle, England

3660. Gillis, J., Stability of a column of rotating viscous liquid, *Proc. Camb. Phil. Soc.* **57,** 1, 152–159, Dec. 1960.

A long column of viscous liquid with a free surface rotates as a rigid body. Conditions are deduced for stability of the free surface. It is found that the surface tension must be greater than $\rho a^3\omega^2/(s^2-1)$, where ρ is the fluid density, a the tube radius, ω the angular velocity and s the wave number of the rotational perturbation. Result is surprising because required surface tension is greater than that for an inviscid liquid even though viscosity does not appear in the result. Author gives a tentative physical explanation for this anomaly. A numerical solution is obtained for a case in which the surface tension is less than critical. It is found that rate of growth of the perturbation does depend on viscosity. W. D. Baines, Canada

3661. Napolitano, L. G., and Pozzi, A., Laminar mixing in the presence of axial pressure gradients, *J. Aerospace Sci.* **28,** 1, 73–75 (Readers' Forum), Jan. 1961.

3662. Kasimov, A. F., The change in concentration of a mixture in the case of subsequent, laminar flow of the liquid along a pipeline (in Azerb.), *Trudî Azerb. Politekhn. In-ta* no. 3, 128–133, 1958; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3909.

A differential equation of motion is set up for the interface between displacing and displaced liquids moving in a cylindrical pressure pipe in conditions of laminar flow. It is remarked that, in the derivation of this equation, the gravitational forces have not been considered, while the pressures at the ends of the pipe are assumed to be time-constant. Reducing the equation of motion to the Cauchy problem, which is solved, the author obtains analytical relationships for the flow rates of the displacing and displaced liquids, at the end of the pipeline. The solution of the problem under examination is accompanied by corresponding calculation tables and graphs. M. E. Faktorovich

Courtesy Referativnyi Zhurnal, USSR

3663. Gravalos, F. G., The dynamics of turbo-flow (in English), *ZAMP* **10,** 4, 347–380, July 1959.

After two short introductory chapters on kinematic relations and force fields in a stationary axially-symmetric inviscid fluid flow the kinematic and dynamic conditions of potential force flows and their structure are investigated. It is shown that in this case two dynamically significant one-parameter families of surfaces exist and that both families coincide if the Bernoulli constant of the flow is zero (Lorenz flows). Two further types of flow are introduced: the von Mises flow and the quasi-potential force flow, in which the external force per unit mass has the form of a product of a scalar function and of a gradient. For this type of flow the hydrodynamic problem is reduced to the solution of two differential equations: the Stokes's equation for the stream function and the hyperbolic equation for an auxiliary function, from which the form of the blade shape can be deduced. The computational work can be carried out in steps so that the flow pattern in the meridional plane can be determined first. Finally, a numerical example with diagrams is given, in which the vorticity distribution in the meridional plane was assumed in correspondence with experimental results obtained by A. R. Howell on axial compressors [*Proc. Instn. Mech. Engrs.* **153,** pp. 441–452, 1945].

A. Kuhelj, Yugoslavia

3664. Huber, D. G., Irrotational motion of two fluid strata towards a line sink, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 4 (*J. Engng. Mech. Div.*), 71–86, Aug. 1960.

The irrotational motion of two incompressible fluids of different density toward a line sink located at the bottom corner of a rectangular box with the upstream end extending to infinity is analyzed by the approximate relaxation procedure.

This motion has been shown to be governed by the Froude numbers in each layer. If the Froude number of the lower stratum is below a critical value (2.76 for the boundary conditions analyzed), the upper fluid is at rest. For higher values the upper fluid begins to flow, the total discharge increases slowly, but the discharge of the heavier fluid decreases as that of the lighter fluid increases. A point is reached, however, when this trend is

changed and both discharges increase together as the Froude numbers approach equality. The shape of the interface and the streamline pattern have been shown to be dependent on the Froude number in the upper layer. G. Noseda, Italy

3665. Filippor, B. V., Determination by known velocity distributions of the shapes of profiles in a potential flow of a perfect, incompressible fluid (in Russian), *Sb. Tr. Povolzbsk. Lesotekbn. In-ta* no. 52, 135–173, 1957 (1958); *Ref. Zb. Mekb.* no. 4, 1959, Rev. 3776.

A solution is presented for the problem of a system of two circles of identical radius in a potential flow emanating from a source situated at the center of the segment connecting the centers of the two circles. Conformal transformation of the exteriors of the circles and sections on the interior of a rectangle in the U-plane is applied, followed by conformal transformation of this rectangle on a region in the plane of the complex potential in the form of a band with two sections. The projections of the velocity on the circumferences are expressed in fractions of the parameter U. From the projections thus established the profile contours are developed. G. G. Tumashev

Courtesy Referativnyi Zhurnal, USSR

3666. Burrows, G., Flow through and blockage of capillary leaks, *Trans. Inst. Chem. Engrs.* **39**, 1, 55–63, 1961.

To help in understanding the behavior of small leaks in vacuum equipment, the various types of gas flow that can occur through small-bore capillaries are considered, and some formulas are derived that represent flow rates under different conditions. The factors that control the flow of liquids through capillaries are reviewed, together with the behavior to be expected when a volatile liquid evaporates from a capillary into a vacuum. The limitations imposed by porosities are examined, taking into account the special features of adsorbed flow. Some causes of capillary blockage are investigated, including surface tension and surface adhesion effects, and the conditions under which the influence of viscosity exerts a significant restriction. The removal of such blockage by a pressure difference and by evaporation is discussed.

From author's summary

3667. Spielberg, K., and Timan, H., On three and two-dimensional disturbances of pipe flow, *ASME Trans.* **82**E (*J. Appl. Mech.*), 3, 381–389, Sept. 1960.

Squire [*Proc. Roy. Soc. Lond.* (*A*) **142**, 612–628, 1933] has shown that for plane Couette motion three-dimensional perturbations have higher critical Reynolds numbers than two-dimensional. Authors show that such a conclusion is not valid in the case of Poiseuille motion. Concerning the known controversy [Lin, "Hydrodynamic stability," Cambr. Univ. Press, 1955, p. 13] authors conclude in favor of stability at finite values of the Reynolds numbers. L. S. Rintel, Israel

3668. Couchet, G., On some movements of an imaginary part of a fluid for which the acting forces of the fluid are identical with the inertia forces on a fictitious solid (in French), *C. R. Acad. Sci. Paris* **250**, 17, 2846–2847, Apr. 1960.

3669. Roy, M., Formation of zones of vorticity in flows with small viscosity (in German), *Z. Flugwiss.* **7**, 8, 217–227, Aug. 1959.

The production of rolled-up vortex sheets, notably near the leading edge of a delta wing, is explained by theoretical considerations and examined in detail by means of numerous flow visualizations.

The paper also includes a discussion of the flow behind a fixed symmetric body at infinite Reynolds number, assuming that it is steady and laminar. If the wake behind the body is of finite length it is shown that the fluid velocity on the axis is greater than at points near the axis. The author argues that on physical grounds one would expect the reverse to be true.

K. Stewartson, England

3670. Ustinov, M. D., The problem of motion of an ideal incompressible liquid near a semi-infinite plate, taking into account detached vortices (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekb. Nauk* no. 9, 120–123, Sept. 1958.

Compressible Flow (Continuum and Noncontinuum Flow)

(See also Revs. 3698, 3702, 3703, 3707, 3710, 3718, 3729, 3732, 3752, 3761, 3777, 3793, 3809, 3820, 3825, 3873, 3884, 3898, 3943)

3671. Sheppard, L. M., Limitations of the sonic area rule, *Aero. Quart.* **11**, 3, 248–254, Aug. 1960.

Some previously published zero-lift drag results [AMR **13**(1960), Rev. 4186] are summarized. G. E. Nitzberg, USA

3672. Petukhor, B. S., Sukomel, A. S., and Mukhin, V. A., An investigation of the coefficient of temperature recovery in the motion of a compressible gas along a circular pipe (in Russian), *Izv. Vyssb. Uchebn. Zavedenii. Energetika* no. 2, 51–57, 1958; *Ref. Zb. Mekb.* no. 4, 1959, Rev. 3933.

Experimental investigations have been made to determine the coefficient of temperature recovery r in a turbulent boundary layer. The experiments were made in a Plexiglas tube of 16-mm diameter, placed in a vacuum chamber. It was found that, within the range of Mach 0.6 to 1.0, and Reynolds numbers 2.65×10^3 to 10^6, $r = 0.893 + 0.005$; for Mach 1.93 to 2.92, and R up to 2.7×10^7, $r = 0.881 \pm 0.005$. The authors take no account of the prehistory of the formation of the boundary layer, nor of the local pressure gradient. The determining criterion is erroneously stated as the value of the Reynolds number for the parameters of a free flow. No account is taken of the influence of radiation between the vacuum chamber casing and the pipe. It is prematurely concluded that r remains constant for varying M and R.

L. N. Shchukin

Courtesy Referativnyi Zhurnal, USSR

3673. Libby, P. A., and Cresci, R. J., Experimental investigation of the downstream influence of stagnation-point mass transfer, *J. Aerospace Sci.* **28**, 1, 51–64, Jan. 1961.

An experimental study of the heat transfer on a hemisphere has been performed at a Mach number of 6 and stagnation temperature of 1600°R in the presence of mass transfer produced by injection of a gas at the stagnation point. This mass injection does not effectively modify the downstream inviscid flow, and the pressure distribution also is not altered. Only the distance to the point of separation is slightly increased. The boundary-layer equations when nondimensional parameters were introduced gave a satisfactory interpretation of the results. Four gases were injected: helium, nitrogen, argon and krypton. Helium was the most effective, but it appeared possible, with the same volume flow, to have better performance with the heavier gases. The experiments were performed with a stagnation pressure of 600 psia and Reynolds number (based on the radius of the hemisphere) of about $2 \cdot 5 \cdot 10^5$. The flow was always laminar and experiments were performed with both uniform wall temperature and the surface adiabatic.

E. A. Brun, France

3674. Larson, H. K., and Keating, S. J., Jr., Transition Reynolds numbers of separated flows at supersonic speeds, NASA TN D-349, 30 pp., Dec. 1960.

Experimental research has been conducted on the effects of wall cooling, Mach number, and unit Reynolds number on the transition Reynolds number of cylindrical, separated boundary layers on an ogive-cylinder model. Results were obtained from pressure and temperature measurements and shadowgraph observations at Mach numbers between 2.06 and 4.24, Reynolds numbers (based on length of separation) between 60,000 and 400,000, and ratios of wall temperature to adiabatic wall temperature between 0.35 and 1.0. Within the range of the present tests, the transition Reynolds number was observed to decrease with increasing wall cooling, increase with increasing Mach number, and increase with increasing unit Reynolds number. From authors' summary

3675. Smith, Harriet J., Experimental and calculated flow fields produced by airplanes flying at supersonic speeds, NASA TN D-621, 24 pp., Nov. 1960.

Results are presented of a flight investigation conducted to survey the flow field generated by airplanes flying at supersonic speeds. The pressure signatures of an F-100, an F-104, and a B-58 airplane, representing widely varying configurations, at distances from 120 to 425 feet from the generating aircraft and at Mach numbers from 1.2 to 1.8 are shown. Calculations made by using Whitham's method gave good agreement with experimental results. A procedure for calculating the $F(y)$ function used in Whitham's method is also given.

From author's summary

3676. Tewfik, O. K., and Giedt, W. H., Heat transfer, recovery factor, and pressure distributions around a circular cylinder normal to a supersonic rarefied-air stream, *J. Aerospace Sci.* **27,** 10, 721-729, Oct. 1960.

Experimental investigation covers range of free-stream Mach numbers from 1.3 to 5.7, and range of free-stream Reynolds numbers (based on body diameter) from 37 to 4,100. Correlations of measurements confirm generally accepted simple results, namely; (a) distributions of heat-transfer coefficients on blunt noses are well predicted by Lees' theory [*Jet Propulsion* **26,** 4, 259-269, Apr. 1956] even for moderately cooled walls (average wall temperatures in the experiments were around 90 and 210°K; stream stagnation temperature was around 300°K); (b) distributions of recovery factors are independent of Mach and Reynolds numbers.

R. Vaglio-Laurin, USA

3677. Holt, M., and Yim, B., Supersonic flow past finite double wedge wings of variable thickness: Part 1, Linear variation; Part 2, Sinusoidal variation, AFOSR TN 60-431; AFOSR TN 60-432 (Brown Univ., Div. Appl. Math.), 32 pp., May 1960; 35 pp., May 1960.

3678. Smith, C. G., Heat-flux distribution over hemispherical-nosed bodies in hypersonic flight, *J. Aerospace Sci.* **28,** 1, 69-71 (Readers' Forum), Jan. 1961.

The purpose of this note is to extend the generalized results of Kemp, Rose and Detra [*J. Aero. Sci.* **26,** 7, 421-430, July 1959; AMR **13** (1960), Rev. 403] in closed forms for the case of a hemisphere-cylinder and clarify the nature of the Mach-number dependence. From author's summary

3679. Wang, K., and Ting, L., Aerodynamic heating of re-entry vehicle, *ARS J.* **30,** 12, 1180-1181 (Tech. Notes), Dec. 1960.

In the present note, it is found that the maximum heating rate takes place at the point of the trajectory very near to the minimum elevation. Again, the fact that the major portion of the heat input also takes place in the same part of trajectory as the velocity is used to obtain the analytic expression for the total heat input. The numerical results for the total heat input check closely with the machine calculations. From authors' summary

3680. Readshaw, D., Predicting temperature rises due to aerodynamic heating, *Aircr. Engng.* **33,** 383, 8-11, Jan. 1961.

Author describes how trajectory data are used to calculate the distribution of temperature throughout the radome of a missile. The problem divides itself into two parts, one being the solution of the heat conduction equation within the medium of the radome, the second being the solution of the boundary condition at the surface.

The method is easily applied to many other problems where a medium is heated by forced convection and in fact three independent problems have been solved using the method described here.

From author's summary

3681. Vaglio-Laurin, R., and Trella, M., A study of flow fields about some typical blunt-nosed slender bodies, AFOSR 2 (Polyt. Inst. Brooklyn, Dept. Aerospace Engng. Appl. Mech., PIBAL Rep. 623), 50 pp., Dec. 1960.

Complete inviscid flow fields about three model axisymmetric configurations have been determined numerically. Configurations (a sphere-cylinder, and two sphere-cone-cylinder combinations of decreasing bluntness) and flight conditions have been selected so as to indicate separately effects of nose shape, drag coefficient, flight Mach number, and thermodynamic behavior of the gas (either ideal calorically perfect gas or air in equilibrium dissociation). Results are presented for thirteen cases. Particular attention is devoted to interpretation and, when possible, correlation of pressure distributions on, and shock shapes about, the cylindrical afterbodies. It is found that: (a) The correlation of pressure distributions on bodies having nonspherical noses involves interpretive modifications of the law suggested by blast wave analogy. Also shocks about these bodies are not described by parabolae; (b) for all configurations there is substantial influence of gas behavior on shock shape; this, however, can be correlated in terms of the gas conditions along a generally defined streamline; (c) the shock layer can generally be divided into two regions (the first bound by the body and the aforementioned streamline, the second delimited by this streamline and the shock) wherein flow properties can either be approximated by simple laws or correlated: (d) for each configuration knowledge of the complete flow field in one flight condition (even pertaining to ideal gas flow) can be used to estimate features of flows under general flight conditions including those where equilibrium dissociation is encountered.

From authors' summary

3682. Maull, D. J., Hypersonic flow over axially symmetric spiked bodies, *J. Fluid Mech.* **8,** 4, 584-592, Aug. 1960.

Experimental results presented in this note were taken at a Mach number of 6.8, a Reynolds number of 0.17×10^6 per inch. The basic body had a diameter of 0.5 inches and its bluntness varied from a flat nose, through various shoulder radii, to a hemisphere.

The optical data obtained are used to define the effect of shoulder radius on the region of oscillatory flow as function of the spike length-to-body diameter ratio (l/d). The apex angle of the dead air region on the spike is also given as function of l/d. Results from this study are combined with those of Mair [*Phil. Mag.* **43,** p. 695, 1952; AMR **5**(1952), Rev. 3498] and Bogdonoff and Vas [*J. Aero/Space Sci.* **26,** 65, 1959; AMR **12**(1959), Rev. 4587] to bracket the (l/d) ratios for oscillatory flows on flat-ended bodies for the Mach number range from 2 to 14.

For those who want to pursue the spiked-blunt-body problem in more detail, reviewer recommends also some earlier work by L. E.

Daniels and H. Yoshihara, "Effects of the upstream influence of a shock wave at supersonic speeds in the presence of a separated boundary layer," WADC TR 54-31, 1954.

H. P. Liepman, USA

3683. Pai, S. I., and Speth, A. I., Shock waves in radiation-magnetogasdynamics, AFOSR 38 (Univ. Maryland, Inst. Fluid Dynam. Appl. Math. TN BN 38), 17 pp. + figs., Nov. 1960.

The general Rankine-Hugoniot relations for a normal shock wave in radiation-magnetogasdynamics have been investigated. It has been found that these relations differ considerably from those without radiation effects, particularly for the case that the gas is initially so hot that the radiation pressure is not negligible. For a given strength of the shock wave, the temperature jump across the shock with radiation effect is much smaller than that without radiation effect.

Various limiting cases have been discussed. In certain cases the results may be expressed in terms of an effective ratio of specific heats γ_e and an effective gas pressure.

A general method of solution by successive approximations is given. Some numerical results are obtained.

From authors' summary

3684. Roy, M., Energy analysis of the structure of a shock wave (in French), *C. R. Acad. Sci. Paris* **251**, 2, 178-181, July 1960.

3685. Teipel, I., Large spherical shock waves including dissociation and ionization effects (in German), *Z. Flugwiss.* **8**, 7, 187-202, July 1960.

Starting from the fundamental equations of gas dynamics, a converging spherical shock wave was calculated, including effects of dissociation and ionization. Behind the shock front the flow is assumed to be quasi-steady, an assumption which gives the exact solution at high pressures for ideal gases of constant specific heats. Hydrogen is used as a medium. The calculation has been carried out step by step till $T = 10{,}000°K$. It is shown that the gas is nearly completely dissociated before the ionization begins. The equations become very simple when the gas behind the shock front has been ionized. From author's summary

3686. Nonweiler, T. R. F., A simplified presentation of shock wave parameters in dissociating air flow, *J. Roy. Aero. Soc.* **64**, 595, 438-439 (Tech. Notes), July 1960.

3687. Germain, P., and Guiraud, J.-P., Condition of shock in a liquid with small coefficients of viscosity and of thermal conductivity (in French), *C. R. Acad. Sci. Paris* **250**, 11, 1965-1967, Mar. 1960.

3688. Cook, M. A., and Udy, L. L., Calibrations of the card-gap test, *ARS J.* **31**, 1, 52-57, Jan. 1961.

The shock waves generated by the standard and some modified donors of the card-gap test and propagated into water through the plastic cards were observed in water by a backlighted aquarium method using streak camera photography. The measured initial shock velocity V_w in water was plotted against the number of cards n and converted by means of shock pressure-velocity calibration data for water to $p_w(n)$ curves. The standard tetryl donor initiated with the recommended Special Engineer Corps electric blasting cap exhibited erratic, low-order detonation; high-order detonation was achieved, however, by doubling the length of the tetryl booster. A 38-gm (3.8-cm diameter, 2.0-cm long) cast 50/50 pentolite donor of higher detonation pressure detonated uniformly high order with the Special Engineer electric blasting cap, thus providing a much broader shock pressure coverage with the same card-gap system and a smaller charge. Pressure calibration measurements were also carried out using low density TNT. The aquarium method is shown not only to provide valuable calibration data for the card-gap test, but also to reveal important information on donor initiation, velocity transients and detonation pressures of donors for the card-gap test. From authors' summary

Book—3689. Devienne, F. M., edited by, Rarefied gas dynamics (Proceedings of the First International Symposium, Nice, France, July 1959), New York, Pergamon Press, Inc., 1960, vi + 442 pp. $17.50.

As usual with symposium proceedings in rapidly developing fields, some of the present papers were printed elsewhere and in more complete form before the proceedings appeared in print, while others describe research that has turned out quite differently in the meantime. In general, for the purposes of a symposium, it would seem worthwhile to concentrate on preprints and to forget about proceedings. Nevertheless, present volume should be of permanent value to workers in the field, since it contains a number of carefully written survey papers, setting the stage for the first symposium.

J. R. Stalder describes the use of low-density wind tunnels in aerodynamic research, while I. Esterman and F. C. Hurlbut in their papers consider techniques of measurements in low-density wind tunnels as well as molecular beam apparatus. Fundamental problems related to Boltzmann equation are surveyed by H. Grad and also by E. P. Gross. F. S. Sherman and L. Talbot compare results of kinetic theory with experimental results in a number of fundamental cases. Several other papers are of considerable interest, such as R. F. Probstein's discussion of the transition between low-density and continuum flow at hypersonic speeds.

The book is not up to the highest standards as far as quality of paper, printing and proof reading are concerned. Reviewer was not able to find any information in the book as to what year the symposium took place. S. B. Berndt, Sweden

3690. Krzywoblocki, M. Z., and Bloomquist, R. E., On heat phenomena on rotating bodies in free molecule flow, *Acta Phys. Austriaca* **12**, 3, 237-245, 1959.

Authors derive energy flux toward a sphere or a circular cylinder moving and spinning in a free molecular flow. This is a straightforward method but with astonishing results, presenting an infinite singularity when velocity of the body approaches zero. But as authors claim that this is due to singular comportment at $s = 0$ of $\int_0^\pi \cos^3\phi \sin\phi \exp(-s^2\cos^2\phi)\, d\phi$ which is so elementary a mistake, present reviewer estimates it is not worth while to pursue the discussion. J. P. Guiraud, France

3691. Waterman, P. C., and Stern, S. A., Separation of gas mixtures in a supersonic jet, *J. Chem. Phys.* **31**, 2, 405-419, Aug. 1959.

As a result of supersonic jet experiments similar to (but more detailed than) those of B. W. Becker and co-workers in Marburg, Germany (1954), the authors report new characteristics of the separation phenomenon including a decay of the effect sufficiently far downstream from the nozzle, reversal of the separation at higher gas pressures, and achievement of separation with equal mass constituents.

A physical mechanism is proposed based upon the assumption that separation is due to the manner in which stream and thermal velocities behave. That is, in a binary gas mixture, if both species of molecules emerge from the nozzle with the same stream velocity and Maxwellean temperature, then the total velocity of each molecule is the vector sum of stream and thermal velocities. Lighter molecules will have larger thermal velocities which will cause them to diverge more rapidly than the heavier ones, thus

producing the separation as observed. The rough calculations based upon this theory are in general agreement with the measured values.

R. E. Bolz, USA

3692. Stern, S. A., Waterman, P. C., and Sinclair, T. F., Separation of gas mixtures in a supersonic jet: Part 2, Behavior of helium-argon mixtures and evidence of shock separation, *J. Chem. Phys.* **33**, 3, 805–813, Sept. 1960.

Authors present in a second paper [see preceding review] on the subject, results of new separation experiments in supersonic jets involving mixtures of two gases, helium and argon, with a large mass difference. The tests covered a much wider range of pressures than their earlier experiments and show in detail the transition from "normal" to reversed separation. The theory used [op. cit.] appears again to predict satisfactorily the observed separation phenomena. The "reversed" separation at higher pressures is attributed to differential pressure diffusion across a standard conical shock front and this mechanism is qualitatively discussed. More sophisticated experimental techniques are required to confirm this proposed shock mechanism.

R. E. Bolz, USA

3693. Broer, L. J. F., and Rietdijk, J. A., Measurements on supersonic free jets, *Appl. Scient. Res.* (*A*) **9**, 6, 465–477, 1960.

An experimental study of round supersonic air jets discharging into quiescent air is described. The initial stagnation enthalpy of the jets was equal to that of the atmosphere. Most of the experiments concerned a fully expanded jet with initial Mach number $M_j = 1.74$. From the experimental results the turbulent Prandtl number and the turbulent coefficient of momentum transfer could be calculated in a large part of the mixing zone of the jets. A mixing parameter K has been introduced and calculated for the jets. The results of this investigation are compared with those obtained for low-speed jets.

From authors' summary

3694. Terekhina, N. N., The propagation of a free, turbulent gas flow (in Russian), Issled. Fiz. Osnov. Rabochego Protessa Topok i Pechei, Alma-Ata, Akad. Nauk KazSSR, 1957, 125–147; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3723.

The results are communicated of an experimental investigation into the propagation of a free, turbulent jet of a compressible gas. The introduction discusses researches dealing with the analysis of the laws governing the propagation of such jets. It is pointed out that the available theoretical results are contradictory and require experimental confirmation. The methods and results are described of investigations on the propagation of a free, turbulent jet of a compressible gas in the starting length for the case of outflow velocities much lower than the speed of sound. The experiments were made with jets of different gases, issuing into air, including hot air. Heating of the air was performed both by flame and by electricity. Similarly, jets of hydrogen, oxygen, carbon dioxide and steam (water vapor) were investigated. In these experiments, the temperature and the dynamic pressure of the issuing jet were measured. The dynamic pressure was measured by a piezometer tube (Pitot tube), while for the temperature measurements, the "method of two thermocouples," with Pt-PtRH and Cu-Con thermocouples, was used. The results of the dynamic pressure and excess temperature measurements are plotted in nondimensional coordinates. The relationship determining the propagation of free, turbulent jets of compressible gases has been studied for the case where the density differential of the test gas is due to change in the temperature or molecular weights of the gases. In the author's opinion these experiments have shown that, in all cases, mixing of jets of different gases follows a unique law. On the example of hydrogen, it is demonstrated that molecular diffusion is of secondary importance compared with molar transfer by turbulence.

Yu.F. Dityakin

Courtesy Referativnyi Zhurnal, USSR

3695. Yen, K. T., On the indeterminateness of the boundary conditions for the mixing of two parallel streams, *ASME Trans.* **82** E (*J. Appl. Mech.*), 3, 390–392, Sept. 1960.

The solution of the problem which has an indeterminateness of one boundary condition in the case of a "real free" mixing (i.e. no restraint except of the straight dividing wall) is made determinate by considering the condition of conservation of momentum in the transverse direction. It is shown that the choice of any boundary condition has an important influence on the interface velocity behind the dividing wall. In the author's solution, for a stream velocity ratio of 0.5 the mixing region deflects toward the higher velocity stream, and for a ratio of zero it deflects toward the stationary fluid.

N. Scholz, Germany

3696. Li, T. Y., Recent advances in nonequilibrium dissociating gasdynamics, *ARS J.* **31**, 2, 170–178, Feb. 1961.

The purpose of this paper is to review some recent advances in the study of gasdynamic problems including effects of chemical reactions. To provide a background for the study the general concepts are outlined briefly. The discussions of the recent developments are restricted to inviscid flow problems only, neglecting viscosity, heat conduction and diffusion. Particular attention is directed to recent advances in analyses of nonequilibrium dissociating gas flows. In the hypersonic flight regime, high stagnation enthalpies sufficient to cause dissociation are realized. When the time to reach equilibrium is comparable with the time it takes for a fluid particle to pass through the flow, then there exist regions of the flow field where nonequilibrium states are encountered. A brief survey of both the linear and the nonlinear methods of treatment of these nonequilibrium flows, including some new developments that have not appeared elsewhere, is presented.

From author's summary

3697. Guiraud, J.-P., Plane Couette flow in a radiating gas (in French), *C. R. Acad. Sci. Paris* **250**, 18, 2997–2999, May 1960.

Boundary Layer

(See also Revs. 3673, 3682, 3686, 3695, 3723, 3724, 3908, 3920, 3921, 3924)

Book—3698. Schlichting, H., Boundary layer theory, 4th ed., (translated from the German by J. Kestin), New York, McGraw-Hill Book Co., Inc., 1960, xx + 647 pp. $16.50.

This new edition of Schlichting's amplified version of his wartime lectures includes a 20% increase in content over that of the previous English edition. The presentation is now sectionalized under the broad headings of Fundamental Laws of Motion for a Viscous Fluid, Laminar Boundary Layers, Transition, and Turbulent Boundary Layers. Of these only the portion on Transition has been altered appreciably, along with a much improved compressible flow chapter in the Laminar section. However, some changes are evident throughout the text.

As in the earlier editions, the Navier-Stokes equations, the boundary-layer concept, and exact solutions are given in some detail. For laminar flows both steady and unsteady, two- and three-dimensional geometries are discussed, as is the influence of suction and compressibility. Some of the new material are Goertler's series solution for nonuniform streams, C. C. Lin's harmonic oscillation theory for nonsteady layers, suction effects on airfoil

lift and drag, consideration of heat transfer to bodies of arbitrary geometry and variable surface temperature, and shock boundary layer interactions. Quite apparent is an increased emphasis upon illustrations of experimental data throughout.

In the virtually rewritten two chapters on transition now appear turbulent spot growth, location of transition by means of impact probes, hot-wire measurements, and the influence of compressibility upon stability. Seven chapters dealing with turbulent flow are quite similar to the earlier text but for a small section on heat transfer.

Unfortunately, as pointed out by the author in his Preface, the present edition is largely that of a 1958 German edition (Third) and the lag time is evident. However, the fundamental nature of the subject matter precludes major changes, and this remains a basic source book for both an introduction to boundary-layer theory and the reference shelf. J. R. Baron, USA

3699. Faulders, C. R., A note on laminar boundary-layer skin friction under the influence of foreign-gas injection, *J. Aerospace Sci.* **28**, 2, 166–167 (Readers' Forum), Feb. 1961.

3700. Acrivos, A., Solution of the laminar boundary layer energy equation at high Prandtl numbers, *Physics of Fluids* **3**, 4, 657–658 (Letters to the Editor), July/Aug. 1960.

3701. Nickel, K., A simplification of the von Karman-Pohlhausen process for boundary layers for rotationally symmetric bodies (in German), *ZAMM* **40**, 10/11, 510–511, Oct./Nov. 1960.

It is indicated that the von Karman momentum equation for an axisymmetric boundary layer can be transformed into a form similar to that for a two-dimensional boundary layer by means of Mangler's transformation. The latter form appears to be more suitable for numerical calculation.

L. Landweber, USA

3702. Kosterin, S. I., and Koshmarov, Yu. A., Turbulent boundary layer on a flat plate in a stream of dissociating gas (in English), *Inter. J. Heat Mass Transfer* **1**, 1, 46–49, June 1960.

Semi-empirical theory of Prandtl's mixing-length theory is used to solve the turbulent boundary layer of a dissociating gas on a flat plate of constant and uniform temperature. The dissociating gas is assumed to be in thermodynamic equilibrium and the Prandtl number of the laminar sublayer and turbulent Prandtl number are both assumed to be unity. The enthalpy is then a function of velocity only. A formula for the velocity profile in the turbulent boundary layer is obtained. No numerical result has been given.

S. I. Pai, USA

3703. Mezhirov, I. I., On the turbulent boundary layer of an imperfect gas, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **24**, 1, 120–128, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

Paper deals with derivation of imperfect gas energy equation for conventional model of two-dimensional turbulent boundary layer. Usual boundary-layer simplifying assumptions and inclusion of molecular viscosity and heat conduction, as well as use of coefficients of turbulent viscosity and turbulent heat conduction (for mean stresses and fluxes), result in form of turbulent boundary-layer energy equation which includes that for laminar boundary layer as special case. Equation differs from corresponding ideal gas expression only by substitution of enthalpy for mean temperature. It is not valid for transition region. After suitable transformation of equation of state for gaseous mixture (such as dissociated air), and pointing out that equations of (mean) motion and continuity remain unchanged, author first discusses steady flow with unit Prandtl number, without boundary heat transfer. Energy equation leads to wall-temperature distribution for dissociated gas, in general lower than for ideal gas. Discussion of Reynolds heat conduction analogy is accompanied by re-definition of Nusselt number (consistent with replacement of temperature by enthalpy), which is then obtained in terms of free-stream Reynolds number, wall-friction coefficient, laminar sublayer, turbulent mixing and free-stream Prandtl numbers, and ratio of laminar sublayer edge to free-stream velocities. For processing dissociated gas experimental data, author recommends replacing temperature recovery coefficient by enthalpy recovery coefficient.

T. Ranov, USA

3704. Blackman, D. R., and Joubert, P. N., The three-dimensional turbulent boundary layer, *J. Roy. Aero. Soc.* **64**, 599, 692–694 (Tech. Notes), Nov. 1960.

Authors made velocity measurements in the three-dimensional boundary layer of a delta wing at various angles of attack in order to experimentally verify Coles's postulate of the law of the wake. They found that by appropriately splitting the measured velocity function, the derived wake function was very similar to Coles's proposed form. Limitations of the experimental arrangement, however, prohibited the comparison of vector directions with that proposed by Coles. J. Laufer, USA

3705. Uram, E. M., A method of calculating velocity distribution for turbulent boundary layers in adverse pressure distributions, *J. Aerospace Sci.* **27**, 9, 659–666, 674, Sept. 1960.

Method is first to calculate momentum thickness by approximate formulas, then to calculate friction coefficients by other formulas. Values of parameters in formula for velocity profile are then obtained from correlations of these parameters with friction coefficient and with momentum thickness in inches. Formula for velocity profile is made up of "log" formula for inner region and a formula of the "velocity defect" type for outer region. Author correlates nondimensional distance from surface at which velocity profile first deviates from "log" profile with momentum thickness in inches. Correlation of a nondimensional quantity with a dimensional quantity, here and in friction formulas, seems questionable.

N. Tetervin, USA

3706. Cooke, J. C., Boundary layers over infinite yawed wings, *Aero. Quart.* **11**, 4, 333–347, Nov. 1960.

A method of calculating turbulent boundary layers is given, making use of a method due to Spence and of an analogy between three-dimensional and axisymmetric boundary layers. It is shown that the displacement thickness is equal to that computed using chordwise components and that the streamwise momentum thickness is approximately equal to the chordwise momentum thickness.

From author's summary by A. N. Petroff, USA

3707. Spence, D. A., Velocity and enthalpy distributions in the compressible turbulent boundary layer on a flat plate, *J. Fluid Mech.* **8**, 3, 368–387, July 1960.

Universal relationships are sought for describing the distributions of velocity, shear stress, and enthalpy in a compressible turbulent boundary layer on a flat plate. For the outer profile, a power law is found to fit a wide range of velocity data by the use of the Howarth-Dorodnitzyn transformation for the distance normal to the wall. The inner profile is approximated by a logarithmic law of the wall employing reference conditions evaluated at the mean enthalpy defined by Eckert [*J. Aero. Sci.* **22**, p. 585, (1955)]. The constants are the same as those used in incompressible flow. Expressions for the shear stress and enthalpy are successively derived on the basis of the velocity laws. These extensions are made by application of the conservation equations to provide an internally consistent set of results. The ratio of eddy momentum diffusivity to eddy thermal diffusivity is assumed constant through

the layer. Good experimental agreement with the predicted heat-transfer coefficient is obtained for correlation with friction coefficient and recovery factor.

A. Q. Eschenroeder, USA

3708. Lilley, G. M., An approximate solution of the turbulent boundary layer equations in incompressible and compressible flow, Coll. Aero. Cranfield, Rep. 134, 48 pp., July 1960.

Solutions of the turbulent boundary-layer equations are obtained by use of a virtual eddy viscosity ν_T in the outer region of the boundary layer (that portion in which the mean velocity varies little from its value outside the shear layer). This eddy viscosity is taken as constant over the outer region except for possible streamwise variation. The method of solution leads to a compatability relation $u_\tau \delta/\nu_T$ = constant (u_τ is the shear velocity and δ the boundary-layer thickness) for moderate to high Reynolds numbers. The numerical value of the constant agrees with that derived by Townsend for the equilibrium of large eddies. Use of the above relation permits solution of an equation analogous to the momentum integral equation for momentum thickness Reynolds number as a function of free-stream velocity and a free parameter. Proper choice for the parameter gives results for negative pressure gradient in agreement with those of Spence and Maskell. Near separation the compatability condition does not apply. Extension to compressible flow is made with relatively minor assumptions and gives skin friction values in approximate agreement with those of Mager for the adiabatic, zero pressure gradient case.

From the author's summary by Mary F. Romig, USA

3709. Kashkarov, V. P., The problem of the two-dimensional boundary of a compressible gas flow (in Russian), Issled. Fiz. Osnov Rab. Prots. Topok i Pechey, Alma Ata, Akad. Nauk KazSSR, 1957, 166–174; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3938.

A theoretical (analytical) solution is presented for the problem of the two-dimensional boundary of a laminar flow, for any arbitrary value of the Prandtl number and on the assumption that the coefficient of dynamic viscosity is a linear function of the temperature. In the integration of the boundary-layer equations, A. A. Dorodnitzyn's method of coordinate transformation is applied, enabling the problem of determining the velocity field of a compressible gas to be reduced to the analogous problem for an incompressible gas.

A. S. Ginevskii

Courtesy Referativnyi Zhurnal, USSR

3710. Cooper, M., Mayo, E. E., Julius, J. D., The influence of low wall temperature on boundary-layer transition and local heat transfer on 2-inch-diameter hemispheres at a Mach number of 4.95 and a Reynolds number per foot of 73.2 × 10^6, NASA TN D-391, 37 pp., July 1960.

Local heat transfer and the location of the boundary-layer transition were made at Langley Field at Mach 4.95 and 400°F stagnation temperature on 2-inch hemispheres by transient-heating analysis. Four tests used precooling. In two of these, the boundary layer changed from laminar to turbulent over wide regions of the hemisphere as it heated. This instability was apparently not the effect of roughness, but of cooling.

C. F. Bonilla, USA

3711. Wisniewski, R. J., and Jack, J. R., Recent studies on the effect of cooling on boundary-layer transition at Mach 4, *J. Aerospace Sci.* **28,** 3, 250–251 (Readers' Forum), Mar. 1961.

3712. Botchov, R., On the mechanism of turbulent transition, *Physics of Fluids* **3,** 6, 1026–1027 (Letters to the Editor), Nov./Dec. 1960.

3713. Tetervin, N., An estimate of the minimum Reynolds number for transition from laminar to turbulent boundary-layer flow by means of energy considerations, U.S. Nav. Ord. Lab. Rep. 6854, 65 pp. + figs., Nov. 1960.

A method is proposed for estimating the minimum Reynolds number (based on momentum thickness) at which a boundary layer can become turbulent. The method is an extension of an analysis for pipe flow by Lin [NAVORD Rept. 2243] based on the principle of minimum dissipation. While a boundary layer is not a minimum dissipation flow, it is assumed that at the critical Reynolds numbers the dissipation is equal for the laminar and turbulent flows. This is equivalent to setting the local friction coefficients for laminar and turbulent flow equal at the transition point. Calculations are presented for a number of compressible flow problems and the results compared with experiment.

W. Squire, USA

3714. Gregory, N., and Walker, W. S., Experiments on the effect of suction on the flow due to a rotating disk, *J. Fluid Mech.* **9,** 2, 225–234, Oct. 1960.

Transition to turbulence in flow over a disk rotating in still air is of interest because it is caused by instability of a secondary-flow profile, as on a sweptback wing. Experiments were made on a disk with a slotted surface to investigate effect of suction on the instability. For *small* rates of suction results were broadly as expected from theory; because of nonuniformity of suction and various imperfections a given increase of stability Reynolds number required about 75% more suction than theoretical value for uniform suction.

For higher rates of suction the reduced radial outflow allowed turbulent "contamination" to spread inward from the outer parts of the disk. Thus instability of secondary flow could not be studied on disk at high rates of suction (and high Reynolds numbers). Because of this limitation, rotating disk is not a satisfactory tool for investigation of effects of suction on secondary-flow instability on sweptback wing at flight Reynolds number.

W. A. Mair, England

3715. Greber, I., Shock-wave laminar-boundary-layer interaction on a convex wall, NASA TN D-512, 28 pp., Oct. 1960.

Author describes an extension to curved surfaces of a theory of shock-induced separation of boundary layers due to Hakkinen, Greber and Trilling [NASA Memo 2-18-59W]. The theory gives a value for the pressure rise required for separation and the length of the separated region. Measurements in a Mach 2 supersonic tunnel confirmed the predicted effect of surface curvature on separation pressure.

J. A. Laurmann, USA

3716. Inger, G. R., An analogy between boundary-layer pressure gradient and chemical reaction-rate effects, *J. Aerospace Sci.* **27,** 12, 956–957 (Readers' Forum), Dec. 1960.

3717. Inger, G. R., Specific heat inequality effect in the chemically frozen stagnation point boundary layer, *ARS J.* **30,** 11, 1028–1029 (Tech. Notes), Nov. 1960.

Book—3718. Stewartson, K., The theory of unsteady laminar boundary layers, Advances in Applied Mechanics, Vol. 6, New York, Academic Press, Inc., 1960, 1–37.

Author presents an excellent review and critical examination of current state of unsteady boundary-layer theory. He discusses Rayleigh-type problems for incompressible and compressible fluids, including kinetic theory approaches; incompressible boundary layers generated by solid boundaries moving impulsively, not necessarily parallel to themselves; initial growth of incompressible boundary layers near leading edges; incompressible boundary

layers on oscillating surfaces; and boundary layers in shock tubes. Current directions of research and unexplored problems are pointed out. I. Greber, USA

3719. Rott, N., and Rosenzweig, M. L., On the response of the laminar boundary layer to small fluctuations of the free-stream velocity, *J. Aerospace Sci.* **27,** 10, 741–747, 787, Oct. 1960.

The linearized treatment of small time-dependent disturbances, initiated by Lighthill, is extended in several ways. In particular, the high-frequency expansion is continued beyond the leading (Stokes) term, and several interesting questions of "joining" are discussed but left unresolved. A practical method for obtaining the response to an impulsive change in velocity is presented. The general results are applied to the particular case of boundary layers of the Falkner and Skan type.

From authors' summary by D. W. Dunn, Canada

3720. Hill, P. G., and Stenning, A. H., Laminar boundary layers in oscillatory flow, *ASME Trans.* **82** D (*J. Basic Engng.*), 3, 593–608, Sept. 1960.

The laminar boundary layers with (Howarth flow close to separation) and without pressure gradient (Blasius flow) subjected to small streamwise uniform, harmonic oscillation of their free velocities, have been studied experimentally and analytically. The results may be classified into three different ranges, low, intermediate and high frequencies. For low-frequency oscillation ($0 \leqslant \bar{x} = x\,\omega/V_m$ where x is distance, parallel to wall, from leading edge, ω is circular frequency of the oscillation and V_m is local free-stream average velocity), the experimental results check with the prediction of the existing theories of Lighthill and of Nickerson. For high-frequency oscillation, the experimental results check with Lin's theory of shear wave. For the intermediate-frequency oscillation ($1.5 < \bar{x} < 10$) the experimental results do not check with the existing theories but check well with the analytical results for intermediate frequency given in this paper.

This paper represents a notable contribution to the subject of unsteady boundary layer even though further studies of unsteady boundary layer are still needed to get better understanding of this complicated flow problem. S. I. Pai, USA

3721. Rozin, L. A., An approximation method for the integration of the equations of a nonstationary laminar boundary layer in an incompressible fluid, NASA TT F-22, 12 pp., May 1960.

Based on the "one-parameter" velocity profiles of steady-flow solution, author gives an approximate solution of the momentum integral equation for unsteady laminar boundary layer of an incompressible fluid. Using some further simplifying assumptions originated from the calculations of steady flow (Hartree problem) and the first approximation for small t (motion with large acceleration), some universal functions can be established. They are then applied to some specific examples.

L. N. Tao, USA

Turbulence

(See also Revs. 3650, 3667, 3698, 3703, 3704, 3705, 3707, 3710, 3712, 3714, 3924)

3722. Monin, A. S., The theory of locally isotropic turbulence, *Soviet Phys.-Doklady* **4,** 2, 271–274, Oct. 1959. (Translation of *Dokladi Akad. Nauk SSSR (N. S.)* **125,** 3, 515–518, Mar./Apr. 1959 by Amer. Inst. Phys., Inc., New York, N. Y.)

Author applies Navier-Stokes equation derived from a moving axis formulation to the derivation of an equation of Kolmogorov governing the velocity structure function in incompressible, locally isotropic turbulence. Using the method, author derives other equations of motion for structure functions.

R. Lyon, England

3723. Lilley, G. M., and Hodgson, T. H., On surface pressure fluctuations in turbulent boundary layers, Coll. Aero., Cranfield, Note 101, 51 pp., Apr. 1960.

In this mathematical paper, a review of theoretical and experimental work on wall pressure fluctuations in turbulent boundary layers is first given. Theory of Kraichnan [*J. Acoust. Soc. Amer.* **28,** 378–390, May 1956; AMR **9**(1956), Rev. 4104] is modified and extended to include the separate effects of the large eddy structure and the convection of the eddies; both the turbulent boundary layer on a flat plate and the wall jet are treated. Incompressible flow is assumed. From preliminary theoretical and experimental results for the wall jet on rms values of the pressure fluctuations, $\sqrt{\overline{p^2}}/\frac{1}{2}\rho u_m^2$, authors suggest that intensity of pressure fluctuations in regions of adverse pressure gradient, on wings and bodies approaching and beyond separation, will be higher than in regions of zero pressure gradient. M. Morduchow, USA

3724. Schultz-Grunow, F., Stability of Couette flow (in German), *ZAMM* **39,** 3/4, 101–110, Mar./Apr. 1959.

This paper is a theoretical and experimental study on the motion stability of a viscous fluid bounded by two coaxial cylinders (the exterior cylinder being in rotation, while the interior is at rest), with applications to viscometry.

Proceding from the Navier-Stokes equations in which the perturbation pressures and velocities are introduced and linearizing the equations with respect of these magnitudes, author determines the stability conditions by using Rayleigh-type solutions for the stream function which yields the perturbation velocities. Problem is reduced to solving a system of two second-order differential equations and the solutions are given under the form of Bessel functions or developments into power series. Generally the motion is stable under the above conditions.

Author has carried out a series of very accurate experiments which, contrary to other previous experimental determinations, confirm the theoretical results. It is shown that experimentally the instability exists due to the geometrical non-accuracies of the device and that generally the turbulence occurs only in case of accelerated motion and then disappears when the steady regime is reached. Under ordinary working conditions (eccentrically placed cylinders, irregular surfaces and so on) the turbulence occurs at the ends of cylinders and propagates toward the middle section.

Paper presents more rigorous calculations than in usual cases. The results are independent of the ratio of the radii of two cylinders and hold valid for any Reynolds numbers. Although its practical interest is rather limited, reviewer believes the study is an interesting complete treatment and brings a contribution to the theory of motion stability between solid walls.

N. S. Tipei, Roumania

3725. Betchov, R., Thermal agitation and turbulence, Space Tech. Lab., Inc., Physical Res. Lab., Los Angeles, Calif. TR 60-0000-AE279, 21 pp., Aug. 1960.

Aerodynamics

(See also Revs. 3669, 3690, 3705, 3706, 3710, 3718, 3761, 3797, 3809, 3825, 3863, 3899)

3726. Stanisic, M. M., On the solution of an integral equation appearing in the delta-wing theory (in English), *ZAMM* **40,** 9, 397–414, Sept. 1960.

Reviewer believes that the equation in question is simply the one which appears in Jones' theory for steady flow at $M = 1$, that is $g(x) = \int \frac{f(y)\,dy}{(x-y)^2}$. Much time is spent with an equation reducible to the preceding one by differentiation. A few comments are given on its use in the problem of unsteady supersonic flow, by expansion in powers of reduced frequency and $(M^2-1)^{1/2}$.

J. P. Guiraud, France

3727. Marchetti, L., On the axial-symmetrical nose of minimum wave drag (in Italian), *Aerotecnica* **39**, 1, 3–6, Feb. 1959.

3728. Cunsolo, D., An investigation on the body nose of minimum wave drag (in Italian), *Aerotecnica* **39**, 1, 7–13, Feb. 1959.

3729. Mattioli, E., Ogive having minimum drag in two-dimensional hypersonic flow (in Italian), *Aerotecnica* **39**, 1, 14–24, Feb. 1959.

3730. Sirazetdinov, T. K., The influence of the nearness of the earth's surface on the distribution of the circulation along the wing's span, the wing having a curvilinear axis (in Russian), *Trudi Kazansk. Aviats. In-ta* **33/34**, 59–67, 1958; *Ref. Zh. Mekh.* no. 9, 1959, Rev. 9880.

The problem is solved regarding the finding of the distribution of the circulation along a wing with a curvilinear axis, taking into account the influence exerted by the earth's surface. The vortex system consists of the combination of a vortex having the form of the mean line of a chord with a vortex shroud. In order to evaluate the influence of the flow boundary, vortices are introduced which are distributed symmetrically relative to the earth's surface. The equation for the transformation is in the form of

$$\Gamma = \frac{1}{2} b \nu_n \cos \chi c_y(\alpha_a) \qquad [1.1]$$

where χ is the angle of sweepback of the section, ν_n the projection of the velocity onto a plane, perpendicular to the axis of the carrying vortex, α_a the actual angle of attack. The expressions for ν_n, α_a through Γ are substituted in equation [1.1]. As the result an integrodifferential equation is obtained. To solve the latter a method of successive approximations is proposed. For the zero approximation the following is adopted:

$$\Gamma^0 = \frac{b \nu_\infty}{2} \cos^2 \chi c_y \left(\frac{\alpha}{\cos \chi} \right)$$

In this case the angle of taper of the flow will be equal to $\Delta\alpha^0 = \Delta\alpha - \delta\alpha$, where $\Delta\alpha$ is the actual angle of taper. An equation is obtained, with an accuracy up to terms of the order $\delta\alpha$ in the resolution of c_y, for the determination of the circulation in the first approximation of Γ^1. The solution merges with that for the solution of a system of algebraical equations. In order to obtain the approximation next in sequence it will be found necessary to substitute Γ^1 by Γ^0 in the obtained equations. The case is worked out separately to determine the linear relationship of c_y to α. Formulas are derived for the forces and moments.

G. G. Tumashev
Courtesy Referativnyi Zhurnal, USSR

3731. Petrauloa, N. N., On the solution of generalized Prandtl problems (in German), *Rev. Mécan. Appl.* **3**, 4, 405–416, 1958.

The Prandtl problem referred to in the title is the classical lifting-line theory of flow past a wing of finite span. It is indicated that a generalization of this theory leads to a set of equations that govern the behavior of a number of other physical problems, such as flow of fluid through porous media or two-dimensional flow past an airfoil with jet flap. It is shown that the generalized equations can be reduced to a linear integral equation with Fredholm-type kernel, and several properties of the solution are discussed. J. R. Spreiter, USA

3732. Destuynder, R., Comparison between experimental unsteady aerodynamic coefficients and those calculated by the piston theory (in French), *Rech. Aéro.* no. 76, 55–56, May/June 1960.

Wind-tunnel results for a wing of trapezoidal planform of aspect ratio 1.5 and diamond airfoil section of thickness ratio 0.04 are given for several Mach numbers from 1.85 to 4.28. They are compared with two sets of calculated results determined by first- and second-order approximations to Ashley's piston theory. The agreement is good at the higher Mach numbers, but only fair at the lower Mach numbers. J. R. Spreiter, USA

3733. Kovar, V., Jet flap measurements carried out in an electrolytic tank (in Czech), *Zpravodaj Vzlu* no. 5 (17), 3–10, 1959.

This paper gives a description of a model method for a two-dimensional airflow over an airfoil with jet flap, carried out in an electrolytic tank. The Malavard model method of airflow circulating around an airfoil profile provided with a jet flap performed in an electrolytic tank has been applied on a 64_1-212 NACA profile which has been used for wind-tunnel measurements. The lift efficiency of the jet flap, the total lift increment, the c.p. and the shape of the jet have been evaluated from the results of measurements in which this method has been used for small angles of incidence. Moreover the course of streamlines over the mentioned airfoil profile with jet modelled from the trailing edge has been measured. The results of measurements are compared with the theoretically calculated values and with the results of wind-tunnel measurements. To get a better idea of the effect exerted upon the airflow by the jet, some pictures showing the flow over an airfoil in a smoke tunnel are presented. From author's summary

3734. Campbell, G. S., Effect of fixed forward fins; changes in lift and moment characteristics of slender aircraft and missiles, *Aircr. Engng.* **32**, 379, 271–274, Sept. 1960.

An estimate is made of the effect on the lift and center of pressure of a slender wing-body combination produced by adding a small forward fin. The fin is assumed to discharge a trailing vortex which interacts with the main lifting surface. Design charts permit rapid estimation of lift loss and center of pressure movement for a delta wing plus body. At the lower angles of attack, the lift loss on the wing is approximately equal to the lift of the forward surface itself. Most of the lift is lost at the front of the wing, and so wing center of pressure moves aft with addition of the forward fin. Theoretical estimates are in general agreement with experimental results at Mach numbers 1.65 and 2.41.

From author's summary

Vibration and Wave Motion in Fluids

(See also Revs. 3654, 3659, 3660, 3682, 3688, 3726, 3747, 3756, 3797, 3801, 3841, 3893)

3735. Walker, M. L., Jr., Kirkpatrick, E. T., and Rouleau, W. T., Viscous dispersion in water hammer, *ASME Trans.* **82** D (*J. Basic Engng.*), 4, 759–764, Dec. 1960.

Authors investigate the influence of the dispersive effect of the viscosity on pressure distribution in water hammer. As a model a compressible liquid is considered to be flowing without wall shear in a rigid conduit of finite length at a constant and uniform velocity. At the downstream end of the conduit a valve is instantaneously closed. Substitution of the continuity equation and the equation of state in the linearized Navier-Stokes equation for one-

dimensional compressible flow leads to the differential equation of the arising water-hammer phenomenon. Its solution by the separation-of-variables method provides expressions as well for the displacement of a fluid particle from its initial position as for the pressure distribution, as functions both of the time and the distance from the valve. The latter is also numerically computed on an IBM 650 computer.

Dispersive effect of viscosity on pressure distribution is shown in diagrams, the conclusions from which are:

Pressure does not increase to the upper bound obtained for inviscid fluids. Viscous dispersion serves to smooth out the stepwise-discontinuous pressure wave front. At the valve, pressure rises gradually, and not instantaneously, as it would in an inviscid fluid. The maximum pressure depends on the length of the conduit. With the increase of this the maximum value of pressure rise asymptotically increases to the usual upper bound of an inviscid fluid.

The dispersive effect of the viscosity is noticeable only either in the case of extraordinarily short conduit or in that of a kinematic viscosity of a far greater order of magnitude than ordinarily encountered. In practical cases, the improvement is negligible.

T. Gerey, Hungary

3736. Longuet-Higgins, M. S., and Stewart, R. W., Changes in the form of short gravity waves on long waves and tidal currents, *J. Fluid Mech.* **8,** 4, 565–583, Aug. 1960.

Short gravity waves, when superposed on much longer waves, have a tendency to become shorter and steeper at the crests of the longer waves, and correspondingly longer and lower in the troughs. The changes in wavelength and amplitude of the shorter waves are calculated by taking into account the nonlinear interactions between the two wave trains (whose first-order terms are assumed to be of the same order of magnitude). The results differ in some essentials from previous estimates by Unna. The variation in energy of the short waves is shown to correspond to work done by the longer waves against the *radiation stress* of the short waves, which had previously been overlooked.

From authors' summary by J. N. Hunt, England

3737. Tadjbakhsh, I., and Keller, J. B., Standing surface waves of finite amplitude, *J. Fluid Mech.* **8,** 3, 442–451, July 1960.

Gravity waves on the surface of an inviscid incompressible fluid of finite depth are considered. The waves are assumed to be periodic in time and in the horizontal direction. The surface profile, potential function, pressure and frequency of the motion are determined (to third order) as series in powers of the amplitude divided by the wavelength. It is found that the frequency increases with amplitude for depths less than a certain multiple of the wavelength and decreases with increasing amplitude for greater depths. Graphs of the surface profile and of the pressure as a function of depth are included.

From authors' summary by S. D. Nigam, India

3738. Ursell, F., On Kelvin's ship-wave pattern, *J. Fluid Mech.* **8,** 3, 418–431, July 1960.

The age-old problem of the waves generated when a concentrated pressure travels with constant velocity over the free surface of water is reexamined. Viscosity and surface tension are ignored, the flow is assumed to be steady and based on the linearized equations. In the earlier treatments of Hogner (1923) and Peters (1949, *Comm. Pure Appl. Math.* **2**) the wave pattern in the vicinity of the track of the pressure point and in the neighborhood of certain critical angles $\theta = \pm\theta_c \doteq \pm 19{:}5^\circ$ was not examined. This is considered in this paper.

S. D. Nigam, India

3739. Kiladze, R. M., The reduction of the wave height in a channel by a lateral spillway (in Russian), *Sakartvelos SSR Metsnierebata Akademiis Moatbe* **18,** 6, 655–662, 1957; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3856.

A method is presented for calculating the relationship between the wave height above the threshold of a spillway, and the distance traveled along the spillway. The solution of the problem is founded on the following assumptions: the slope of the channel bottom and the frictional losses within the limits of the lateral spillway are insignificant and negligible; the line of the free surface on the first establishment of a steady flow coincides with the threshold of the spillway, or is parallel thereto. The general, differential equations of unidimensional, unsteady flow in the presence of a diverging outflow along the path, can be written

$$\frac{\partial F}{\partial t} + \frac{\partial (Fu)}{\partial s} + q = 0$$

$$\frac{1}{g}\left(u\frac{\partial u}{\partial s} + \frac{\partial u}{\partial t}\right) = -\frac{1}{b}\frac{\partial F}{\partial s} + \frac{q}{gF}(u - \theta);$$

wherein θ is the projection of the velocity of the separating masses on the direction of the primary flow; q the unit flow volume of the lateral spillway. Differential equations are written for two families of characteristics corresponding to waves propagating with and against the direction of flow respectively. An analysis of the returning positive wave is made, and the formulas for calculating the wave height in relation to the distance it has traveled along the spillway are set up. The final formulas contain a correction term σ, representing the transverse acceleration of the liquid efflux from the body of the wave into the lateral spillway, which is determined experimentally. It is assumed from experimental data that the coefficient σ may be regarded as a constant.

S. S. Boit

Courtesy Referativnyi Zhurnal, USSR

3740. Holl, J. W., An effect of air content on the occurrence of cavitation, *ASME Trans.* **82** D (*J. Basic Engng.*), 4, 941–946, Dec. 1960.

The simultaneous occurrence of vaporous and gaseous cavitation on hydrofoils is considered. The experimental results show that gaseous cavitation occurs at much higher ambient pressures than that for the vaporous cavitation resulting in desinent-cavitation numbers twice the minimum-pressure coefficient of the hydrofoil. The analysis indicates that the difference between the desinent-cavitation number for the gaseous cavitation and that for the vaporous cavitation is proportional to the dissolved air content and inversely proportional to the square of the velocity.

From author's summary by J. S. Marcus, USA

3741. Katto, Y., Some fundamental natures of resonant surge: Part 1, Experimental results and analysis of oscillating systems; Part 2, Theoretical analysis, *Bull. JSME* **3,** 12, 484–495, Nov. 1960.

A resonant surge of small fan-duct systems has been investigated to clarify the fundamental natures of the oscillating phenomenon of this kind. The first report gives the details of the experimental apparatus and also of the results obtained. The values of frequency of oscillation measured have been used to analyze the systems to provide the equivalent lumped models for use in the theoretical analysis of the surge described in the second part.

The oscillation cycles of the fan-duct systems with nonlinear forcing have been determined by phase plane integrations utilizing the equivalent lumped models obtained in Part I. It has been assumed that the instantaneous characteristics of the fan are the same as its static ones. Experimental and theoretical results have been found to agree well with each other.

Although the fan-duct systems chosen were simple ones and the fan pressure rise was only a few inches of water, it seems likely that the fundamental natures of surge have been clarified.

From author's summary

Fluid Machinery

(See also Revs. 3447, 3619, 3654, 3655, 3656, 3663, 3740, 3741, 3809, 3941)

Book—3742. Pfleiderer, C., Fluid flow machinery [Stromungsmaschinen], 2nd ed., Berlin, Springer-Verlag, 1957, xiv + 421 pp.

Title work can not be dealt with in the usual reviewing method. Style of the work is attractively new, therefore it catches the attention of all technicians in fluid flow machinery. In it, the late Prof. Pfleiderer, master of pump research, discusses the whole of fluid flow machinery, i.e. water turbines, stream turbines, gas turbines, pumps, blowers and compressors, from his own newly initiated point of view. His intention is to treat the different fluid flow machines in a common and over-all respect. This intention succeeds excellently, because different machines are put in an integrated frame of wide horizon; at the same time it gives a clear-cut survey of the author's considerable research results and design methods in pump construction.

The manner with which he presents the operational principles of machines is extraordinarily plain and it is immediately understandable. The parallel presentation and comparison of the cognate fields is brilliant. He gives universal principles and definitions. His arrangement offers an excellent perspicuity of machines. This method of treatment by itself calls the reader's attention to many till now one-sided erroneous views. E.g. axial machines are usually placed by water turbine designers mostly among the range of reaction turbines of highest specific speed. This work points out that this is not correct even in the field of water turbines.

Chapter 1 of this revised edition deals with the structure of flow in the runner. In it, the discussion of head and efficiency is of special interest. Dimensionless coefficients are presented uniformly and their meanings are shown. The treatment of efficiency and specific speed puts a clear face on the matter. The well-known Pfleiderer method of the discussion of cavitation and transonic phenomena [*ZVDI* **92**, 1950] signifies a new impulse to cavitation research.

Chapters 2 and 3 survey the runner design of various fluid flow machines.

The next three chapters review the characteristics and model laws of machines, the leakage losses and the axial thrust, also the guide apparatus.

Chapter 7 is particularly remarkable for the detailed discussion of different types of axial runners. The comparative treatment of runners with a close as well as with a wide spacing of the vanes illuminates one of the most difficult topics.

Chapter 8 deals with multistage systems of turbines and compressors. The setting of single fundamental and constructional accomplishments side by side, the critical analysis of advantages and disadvantages are exemplary.

Chapter 9 deals with characteristics in case of compressible media.

The last chapter illustrates some special problems—mostly from the field of thermodynamics—of fluid flow machines running with compressible media.

The work ends with a very well-chosen bibliography which takes into consideration the new publications since first edition was published five years earlier.

Pfleiderer's contribution to pump research is of exceedingly great importance; perhaps he is the main scientist whose activity advanced the pump design from art to science. The work reflects brilliantly author's deep knowledge and significance of his scientific life-work, bridging a half century; he also takes account of recent fields.

He wishes to bestow an over-all unified basis for students, in default of which during academic studies the scope of knowledge of individual similar fields often can not be developed on a common basis, but on the contrary, become confused. His method however could offer splendid conceptions for designers in constructing machines and especially for researchers.

The exterior of the book is worthy of its content, and the numerous illustrations are rich in information.

Reviewer's opinion is that this valuable inspiring book should take its place as a standard work on the desk of every engineer and student engaged in fluid flow machinery.

T. Gerey, Hungary

3743. Rakhmanovich, A. N., The analysis of a three-dimensional flow in a cascade (in Russian), Ufimsk. Gor. Nauchno-Tekhn. Konferentsiya, Posvyashch. Vypolneniyu Direktiv XX Sbezda KPSS po Tekhn. Progressu v Prom-sti, Ufa, 1957, 147–171; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3711.

The results are presented of the experimental investigation of a three-dimensional flow in a convergent cascade at low incident velocities ($M = 0.3$). An original design of an arrangement with elastic rubber blades is described which enables variation of the parameters of the two-dimensional cascade, and the angle of twist of the profile over the depth of the blade. Sketches are included of a series of miniature nozzles for measuring the flow parameters, but no comparative data of the measurements with different nozzle forms are given. The measurements were made in the blade ducts in fifteen cross sections over the depth of the blade, as well as behind the cascade at distances of 2 and 15 millimeters (0.05–0.08, and 0.42–0.62 of the blade pitch). The flow was made visible by means of specially suspended and moveable tufts, illuminated by an electronically-controlled stroboscope. The singularities of the velocity field in the blade gap are specially examined and a criterion of steady flow in a curvilinear duct derived therefrom. The results are communicated of an experiment made to determine the influence of obliquity of the stream lines in the boundary layer. Detailed data are given on the influence of the parameters of a convergent cascade on the structure of the flow in depth. In addition to plane cascades, tests were made with blades having a large angle of twist in depth (of the order of 100–120°). The influence of the radial clearance on the character of the flow at the discharge from the cascade has been determined experimentally. Author attempts to analyze the results of these experiments on the basis of the theory of similarity, and non-dimensional similarity criteria for blade cascades, with and without a radial clearance, are presented.

A. I. Bunimovich

Courtesy Referativnyi Zhurnal, USSR

3744. Shchipulin, I. F., The characteristics of the working process in an oblique-flow hydraulic turbine in relation to the energy balance in the turbine flow (in Russian), *Trudi Vses. Nauk i In-ta Gidromashinostr.* no. 21, 76–95, 1958; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3891.

From investigation on turbine models the energy balance of the flow in an oblique-flow turbine is set up, and the influence of design factors and working conditions on the losses in the individual parts of the turbine is investigated. Mechanical and pumping losses have been measured by running the turbine rotor dry (without water) at different speeds, using motor balances. The pumping

losses are determined as the difference between the mechanical-cum-pumping losses as measured, and the frictional losses in the bearings, as found in a special test with a naked rotor. The mechanical losses were determined for different values of radial and axial forces, artificially applied to the turbine shaft. It has been found that the magnitude of the mechanical losses is perceptibly influenced by the loads on the bearings. The efficiency of the guide ring was found as the ratio of the squares of the actual and theoretical outflow velocities at the nozzle. The overall hydraulic losses in the rotor blades were calculated by the Bernoulli equation for the case of relative motion. The volumetric efficiency was assumed to be unity in optimum and nearly optimum conditions. A wide divergence was found between the optimum working condition of the turbine, and the conditions in which the rotor and guide ring are working at their maximum efficiencies. As a result of investigations on rotors running at different speeds, it has been found that the optimum running speed for an oblique-flow turbine is 33, which is twice that for a bucket-type wheel. It was also found that the decisive factor influencing the economy of an oblique-flow turbine is represented by the losses in the guide ring and rotor blades. Each of these loss factors may amount to 5–6%. Exit losses are usually of the order of 2–2½%. With deviation from optimum running conditions, the blade and exit losses increase. Owing to present lack of operating experience, oblique-flow can as yet only be recommended for low and medium powers, with heads from 10 to 300 meters. An experimental installation of an oblique-flow turbine with a wheel of 660-mm diameter, built in the factory and intended for a hydroelectric power station, is described. D. G. Butaev

Courtesy Referativnyi Zhurnal, USSR

3745. Knoernschild, E. M., The radial turbine, for low specific speeds and low velocity factors, *ASME Trans.* **83** A (*J. Engng. Power*), 1, 1–8, Jan. 1961.

The main factors which influence radial-turbine performance are discussed. After a short description of the losses in radial turbines, the concept of the diffusion parameter is introduced. It is shown how the turbine geometry influences performance and, in particular, the reaction. The influence of a variation of the reaction on performance of radial turbines with high and low specific speed is discussed. Three-dimensional effects appear especially in the exducer region of the turbine. They may contribute to backflow and to a distorted distribution of the meridional velocity.

The basic approach to improving turbines in the range of low-velocity factors and low specific speed is indicated. It appears that an attempt to reach impulse conditions in radial turbines is difficult, and only a rather small efficiency improvement can be expected. The approach to be taken in adapting a turbine design to low-specific-speed operation is pointed out, and the deterioration of the blade loading pattern due to such a reduction of the specific speed is shown. From author's summary

3746. Weatherwax, W. F., Design and development of a convective air-cooled turbine and test facility, *ASME Trans.* **83** A (*J. Engng. Power*), 1, 9–18, Jan. 1961.

Demands for higher jet engine thrust-to-weight ratios to satisfy the needs for high Mach number and vertical take-off aircraft are continually increasing. Since World War II, the three-fold increase in thrust-to-weight ratio can be attributed almost entirely to the development of lightweight construction and the axial-flow compressor, and little credit can be given to the meager 200-F increase in turbine-inlet temperature. Increasing turbine-inlet temperature, beyond present-day material limits of 1600–1700 F, by convective air cooling, will increase the jet-engine thrust-to-weight ratio and will markedly improve the performance of the turboprop and bypass engines. The partial results of a program undertaken by the author's company to develop a fully cooled, flight-type, turbine and test facility are reported. The design heat-transfer considerations are discussed, the test facility described, and performance results to date are given. From author's summary

3747. Grindell, A. G., Correlation of cavitation inception data for a centrifugal pump operating in water and in sodium-potassium alloy (NaK), *ASME Trans.* **82** D (*J. Basic Engng.*), 4, 821–828, Dec. 1960.

Author proposes a relationship which would allow correlation of data on cavitation inception in centrifugal pumps, using water systems with cavitation inception in nonaqueous media. He suggests that cavitation inception in nonaqueous media may be estimated by adding the difference between vapor pressures of the liquid and water for same conditions of pump speed and liquid flow to the water-test cavitation inception value. Empirical data for a NaK system at 1500 F shows a correlation within about 5%.

Experimental data are limited and additional data using other liquids and better temperature measurements should be determined to test validity of author's hypothesis.

J. S. Marcus, USA

3748. Itaya, S., and Nishikawa, T., Studies on the volute pump handling viscous fluids: Part 1, Representation method of oil-pumping characteristics, *Bull. JSME* **3**, 12, 456–462, Nov. 1960.

Recently there has been a heavy increase in the demand for volute pumps handling viscous fluids for chemical industries. It is suggested that the properties of viscous fluid influence the hydraulic performance of a centrifugal pump as compared with action of water, and already a few scholars have reported on this influence. It seems, however, that there remain many problems unsettled as to the pumping behavior of a volute pump handling viscous fluids.

The authors measured the hydraulic performance characteristics of a 75-mm volute pump under various pumping conditions in order to analyze their characteristics. In this paper they describe the method of representing all the properties under various conditions and show the performance characteristic diagrams indicating the the influence of viscosity. From authors' summary

3749. Yamamasu, M., A study of the flow of water and bubbles through centrifugal pump impellers, *Bull. JSME* **3**, 12, 463–469, Nov. 1960.

A method to measure the velocity distribution in a centrifugal pump impeller is developed by using two types of streamline photographs; one is the photograph of the streamline relative to the impeller vanes, and the other is that of the absolute streamline. With the same method, the flow velocities of the bubbles of cavitation which appear in the flow through the impeller are also measured. The results of these measurements have shown that the velocities of bubbles are much larger than those of the water at the same discharge. Thus the cavitating flow of water is assumed to be a kind of compressible fluid mixed with vapor bubbles. By solving the equation of motion of this assumed compressible fluid, the velocity distributions of the bubble flows which are measured in this experiment, and at the same time, the mechanism of cavitation shocks, are explained. From author's summary

3750. Yokoyama, S., Effect of the tip shape at entrance of the impeller vane of the centrifugal pump on cavitation, *Bull. JSME* **3**, 11, 326–332, Aug. 1960.

An experimental study on the effect of the tip shape at entrance of the impeller vane of the centrifugal pump on cavitation was conducted by the writer with a vertical-type centrifugal pump.

The experiments were carried out on three different types of tip shape. In each case, the head-capacity curve, the static pressure

distribution on the surfaces of the vanes near the entrance tips and the modes of cavitation occurence were measured.

Results of the experiments are as follows:

(1) At the shockless entry there are more chances of cavitation for the round tip vane than for the other type vanes. For the sharp tip vane no cavitation occurs in the experiments.

(2) Except at the shockless entry, in spite of the discrepancy of the vane tip shapes, incipient cavitation occurs in each vane at the same relative velocity and suction head.

Further, those facts mentioned above are considered to be natural from the pressure distributions on the vane surfaces.

J. C. Geyer, USA

3751. Likhterov, B. M., Analysis of test results on axial compressors in gas turbine installations with large working region (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 6, 59–67, Nov./Dec. 1959.

Paper deals with more precise method of theoretical prediction of axial compressor performance based on usual results of cascade wind-tunnel testing.

Two equal compressors having 11 stages with blade length 81 mm and 39 mm in the first and last stage respectively were realized using Howell's design procedure. Experiments on both machines gave adiabatic efficiency 5–7% greater and pressure ratio higher than theoretical values. The discrepancy between experimental and theoretical characteristics was proportional to the rotational speed. Author shows two main causes: 1. Calculations practically neglect the radial gap; 2. applications of present values of work-done factor Ω have no meaning.

An analysis is then made by which coefficients expressing the effect of the radial gap on compressor characteristics were developed. Author states the experimental and calculated values of these coefficients differ no more than 0.8%.

New expression for the well-known work-done factor Ω is suggested: $\Omega = \Omega' - \Delta\Omega$, where Ω' is a function mainly of the axial inlet velocity and maximum axial outlet velocity according the cascade wind-tunnel tests. Term $\Delta\Omega$ is given by $\Delta\Omega = k\psi'(n-1)/R\Lambda$ where $k = 0.003$, ψ' is the theoretical stage loading coefficient, n is number of stages, R is the reaction, and Λ blade aspect ratio.

Using this method it was possible to attain more accurate agreement between theory and experiment. Curves for adiabatic efficiency differ no more than 1.5% and there are practically no differences in surge lines. M. Horejsi, Czechoslovakia

3752. Dallenbach, F., and Van Le, N., Supersonic diffuser for radial and mixed flow compressors, *ASME Trans.* **82** D (*J. Basic Engng.*), 4, 973–979, Dec. 1960.

Authors present design data for diffusers for radial and mixed-flow compressors incorporating vanes with slanted leading edges (V-notch) to handle supersonic velocities efficiently. Complete diffusing system comprises a semivaneless space with extended V-shape guide, a set of guide vanes, an annular elbow and a set of de-swirl vanes discharging the air axially without swirl. An experimental compressor showed a diffuser isentropic efficiency (based on discharge total pressure) of about 72 per cent at the design inlet Mach number of 1.132 with a 41-vane diffuser set. With a 29-vane set, the design point efficiency was increased to over 76 per cent, with a peak value of 79.2 at Mach 1.30.

D. G. Shepherd, USA

3753. Morgan, W. B., The design of counterrotating propellers using Lerbs' theory, Soc. Nav. Arch. Mar. Engrs., Spring Meet., Washington, D. C., May 26–28, 1960; Adv. Pap. 1, 26 pp.

Lifting-line theory. Method of induction factors is applied which leads to an integrodifferential equation for the bound circulation. Test results show very close agreement both relative to number of revolutions and torque balance. H. W. Lerbs, Germany

3754. Semenov, L. A., The determination of the lift and drag of rotatable propeller shrouds (in Russian), *Sudostroenie* no. 9, 6–10, 1957; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3811.

A method is described which enables analytical verification of the hydrodynamic characteristics of rotatable guide blades associated with screw propellers. The solution of the problem of the hydrodynamics of a rotatable propeller shroud is based on the assumption that such a shroud can be equated to a circular ring, surrounding the propeller. This annular airfoil is considered as being made up of an infinity of rectilinear blade elements, the vortex train represented by the rotatable shroud being regarded as an annular lift line (an attached vortex) of varying intensity, associated with a system of shedding free vortices forming a vortex sheet behind the shroud. In order to determine, quantitatively, the profile drag of any element of the shroud ring, a suitable experiment was made; as a result, nondimensional lift and drag coefficients for the case of a rotatable shroud have been determined. This is followed by a discussion of the sequence of verifying calculations for the hydrodynamic coefficients of a rotatable propeller shroud. Correlation of the analytical results obtained by the methods described with the experimental data, obtained at different times by tank tests, has shown that the divergence between the theoretical and the experimental values of the lift and drag coefficients does not exceed 20%. I. V. Girs

Courtesy Referativnyi Zhurnal, USSR

3755. Heffner, F. E., A general method for correlating labyrinth-seal leak-rate data, *ASME Trans.* **82** D (*J. Basic Engng.*), 2, 265–275, June 1960.

Paper presents method of correlating test data which makes it possible to predict leak rates through a family of seals from tests of only two characteristic seals. Paper and discussion should be of interest to designers. N. H. Johannesen, England

Flow and Flight Test Techniques and Measurements

(See also Revs. 3423, 3424, 3574, 3632, 3653, 3732, 3733, 3735, 3749, 3802, 3839, 3898, 3925)

3756. Benedict, R. P., The response of a pressure-sensing system, *ASME Trans.* **82** D (*J. Basic Engng.*), 2, 482–488, June 1960.

A first-order, first-degree, linear expression is developed to describe the transient behavior of a capillary tubing pressure-sensing system. Comparison is made between linear and nonlinear expressions and experiments. Author recommends the linear equation developed to represent transient response time be used for simplicity, utility and good accuracy.

W. H. Sparing, USA

3757. Bobrik, M. J., A simple method of estimating the vortex intensity, *J. Aerospace Sci.* **27**, 12, 957–958 (Readers' Forum), Dec. 1960.

Paper describes instrument for estimating intensity of single rolled-up vortex from core angular velocity and total-pressure reduction at center. Author assumes solid-body rotation, constant axial velocity in core, and incompressible flow.

R. C. Pankhurst, England

3758. Barbe, A., and Nougaro, J., Determination of the characteristics of a measuring system for the study of rapidly changing water levels (in French), *C. R. Acad. Sci. Paris* **250**, 3, 460–462, Jan. 1960.

3759. Calvet, P., A method of thermal measurements in hypersonic wind tunnels (in French), *C. R. Acad. Sci. Paris* **250**, 19, 3111–3113, May 1960.

3760. Chuan, R. L., Springer, L. M., and Walter, S. A., Operation and calibration of the low density wind tunnel, AFOSR TN 60-649 (Univ. So. Calif. Engng. Center Rep. 56-215), 39 pp., July 1960.

A comprehensive description of a low-density wind tunnel is presented. The tunnel is practically continuous (10-hr max running time) and the vacuum (down to 10^{-5} mm Hg) is maintained by a cryopump.

Limited calibration results from tests with different stagnation temperatures and with a conical nozzle (19-in. outlet diameter) for $M = 8$ show very large viscous effects (the usable test core is about 4 inch in diameter) and decreasing M number with increasing stagnation temperature. The latter effect is treated theoretically in an appendix, too. K. Fristedt, Sweden

3761. Charwat, A. F., A survey of hypersonic problems and the characteristics of shock-heated tunnels (in English), *Z. Flugwiss.* **8**, 5, 125–134, May 1960.

The first part of this paper contains a discussion of the different physical problems of hypersonic flow; the purpose is to establish a similarity map for evaluating the range of application of various proposed experimental facilities. By means of simple order-of-magnitude considerations characteristic parameters are defined which account for the relative importance of the following phenomena: hypersonic velocity, heat transfer (laminar or turbulent), viscous interaction (between the boundary layer and the internal flow field), rarefaction, thermochemical effects and chemical nonequilibrium. Lines of constant values for these parameters are drawn on a M-R_e chart on which the typical ballistic reentry range is also shown. Reviewer believes that the picture would have been interesting if it had been completed with considerations of ionization with magnetohydrodynamic effects. Author shows that some of the above effects cannot be correctly simulated on small scale models.

In the second part, the method of simulating hypersonic flows by shock-heating is discussed by a brief presentation of the different practical facilities developed so far; straight shock tubes, hypersonic shock-tunnels, the Cornell "wave superheater," and so on. Special consideration is given to the hypersonic shock tunnel and its improvements, e.g., interface tailoring (see AMR **13**(1960), Rev. 1919), multiple diaphragms and combustion heating.

This survey is very useful for any research body undertaking the development of a hypersonic experimental facility. In the reviewer's opinion, however, electrical discharge and electromagnetically driven shock tubes provide an attractive alternative, and their inclusion in the survey for the sake of comparison would have been of interest. L. Z. Dumitrescu, Roumania

3762. Eschenroeder, A. Q., and Daiber, J. W., Nonequilibrium ionization in a shock tunnel flow, *ARS J.* **31**, 1, 94–96 (Tech. Notes), Jan. 1961.

An approximate method for calculating nonequilibrium degrees of ionization in adiabatic quasi one-dimensional expanding flows is used for the case of weak interaction between the rate processes and the gasdynamic flow. Results are shown for air flow in a hypersonic shock tunnel nozzle, and the effects of nonequilibrium ionization on electromagnetic wave propagation are estimated for conditions at the tunnel test section.

From authors' summary

3763. Gloersen, P., Some unexpected results of shock-heating xenon, *Physics of Fluids* **3**, 6, 857–870, Nov./Dec. 1960.

Results from a detailed experimental study of the structure of pressure-driven incident shock waves in very pure xenon contained in a thoroughly pumped Pyrex shock tube are presented and discussed. As a result of some optical studies of the luminous structure of the shocks, the following features of the luminosity delay time were discovered: independence of the pressure in the undisturbed xenon in the range 0.75 to 4.0 mm Hg, dependence on shock velocity in a way not explainable on the basis of reasonable volume processes alone, and dependence on shock tube diameter. The visible luminosity from the shock was found to terminate well in advance of the measured position of the xenon-driver interface. This is indicative of severe radiation cooling. The visible luminosity was also found to be profoundly altered by the addition of impurities either in the xenon itself or in the driver. The spectrum of the delayed luminosity in the region from 3000 to 10,000 A was studied with an electronic-recording time-resolving spectrometer and found to consist of xenon atom lines superimposed on a strong continuum. The continuum may reasonably be attributed to dissociative transitions from bound excited states of the Xe_2 molecule related to the xenon atom levels $7\,p_{K\,J}$ and above to unbound Xe_2 states related to the atomic levels $6s_{11}$ and $6s_{12}$. Positive electrical signals, observed during the passage of the shock through external metal rings, are attributed to ejection of electrons from the shock tube walls by photoelectric action and/or metastable atoms. In addition, two different types of electrical precursors were observed. The first was observed under the usual conditions, namely that the shock was sufficiently strong to cause the delayed luminosity. The second was observed in some experiments in which the shock was too weak to cause the delayed luminosity. Both could be due to a photoelectric effect on the shock tube walls, but the precursor observed in the absence of the delayed luminosity may be also due to diffusion of electrons ahead of the shock front. The present experiments strongly indicate that shock tube experiments of others may need reinterpretation.

From author's summary

3764. Christiansen, W. H., Use of fine unheated wires in shock tubes, *Physics of Fluids* **3**, 6, 1027–1028 (Letters to the Editor), Nov./Dec. 1960.

3765. Woods, B. A., Calculation of the recoil of a shock tube, Aero. Res. Counc. Lond. Curr. Pap. 486, 15 pp., 1960.

3766. Silberman, E., and Ripken, J. F., The St. Anthony Falls Hydraulic Laboratory gravity-flow free-jet water tunnel, Univ. Minn., St. Anthony Falls Hydraulic Lab. Tech. Pap. no. 24, Series B, 45 pp., Aug. 1959.

This is a summary of 10 years of development of this unique research facility, which produces by gravity in a vertical conduit a test jet, surrounded by an air-filled chamber, the pressure of which can be lowered to the vapor pressure of the stream.

The water tunnel utilizes the 50-ft elevation difference between the upper and lower pools and serves as a connection between them without recirculation. Its upper section consists of a 30-in. regulating inlet valve, a short pipe and a miter elbow leading to the nozzle. The 24-in. lower section ends in an elbow leading to the vertical outlet control valve at the lower pool. The test section between these has a greater diameter than the lower section, so that it can be telescoped over it, thus providing access to the test chamber for the support of test bodies and instruments. Two alternately mountable nozzles are provided, one for a 10-in. axisymmetric jet and another for a two-dimensional jet, which is 5 in. thick between rigid walls and has adjustable width at the free boundaries of 6 to 15 in.

The jet streams and cavities are observable through plexiglass viewing windows, which serve as rigid walls for the rectangular end of the jet and are properly shaped for the round jet.

A dynamometer was constructed for the rectangular jet, to measure lift, drag and moment of hydrofoils under various settings. It is a null balance instrument in which the test body under load is brought back to no load position by application of extemal forces and moments, measured by load-cells.

With jets up to 40 in. long at velocities up to 50 fps cavitation research was conducted at the very low coefficients of $\sigma \leqq 0.01$. Research with hydrofoils is in progress.

A. Hollander, USA

3767. Danis, R. P., The epicycle method for the reduction of flight-test data using a digital computer, *J. Aerospace Sci.* **27,** 12, 913–920, Dec. 1960.

According to author's introduction: "in re-entry flight tests the airborne instrumentation is usually limited to internal measurement of the vehicle motions. The problem facing the analyst, then, is to determine the angle-of-attack envelope and the stability characteristics of a re-entry vehicle (in terms of the moment and force coefficients), given only telemetered measurements of the angular rates and linear accelerations . . . ." Author treats this difficult problem by representing the motion as an epicycle in a body-fixed reference system; this provides filtering of the rate data, even when they contain considerable noise. The method is restricted to small angles of attack. Data reduction by an iterative procedure on a digital computer is described, and some details of a Datatron-Routine for a best-fit epicycle given. From examples shown, the method gives very good convergence.

Reviewer thinks that this paper provides a fascinating glimpse into problems of which relatively few applied mathematicians have direct experience. F. C. Roesler, England

Thermodynamics

(See also Revs. 3441, 3763, 3803, 3806, 3894)

3768. Krupkowski, A., On the partial thermodynamic functions, *Bull. Acad. Polonaise Sci.* **8,** 4, 199–207, 1960.

Author applies his concept of a "substitute pressure" [AMR 10(1957), Rev. 547] to the calculation of the thermodynamic properties of a substance in solution. Identity of "substitute pressure" with previously established "activity" reduces paper to an algebraic exercise. H. E. Brandmaier, USA

3769. Ackeret, J., The role of entropy in the aerospace sciences, *J. Aerospace Sci.* **28,** 2, 81–95, Feb. 1961.

3770. English, R. E., and Slone, H. O., Comparison of gas-turbine cycles for space applications, *ARS J.* **30,** 11, 1097–1098 (Tech. Notes), Nov. 1960.

On the basis of the radiator area required for rejecting cycle waste heat, Rankine vapor cycles are far superior to the basic Brayton gas cycle for space turbogenerating powerplants. The present analysis considers modifications of the basic Brayton cycle and compares the modified cycles to the basic cycle with radiator area as the criterion of merit. The results indicate that reductions in radiator area attainable by modifying the basic Brayton cycle are small, and thus the competitive position of gas-turbine cycles relative to Rankine vapor cycles is unchanged.

From authors' summary

3771. Parulekar, B. B., Performance of short vortex tube, *J. Instn. Engrs., India* **40,** 12 (Part 2), 409–418, Aug. 1960.

Book—3772. Haywood, R. W., edited by, Thermodynamic tables and other data, 2nd ed., New York, Cambridge University Press, 1960, 23 pp. $0.50. (Paperbound)

In this second edition—see AMR 10(1957), Rev. 1220 for a review of the first edition—"minor corrections have been made to the text where necessary; and Table XI on the properties of Freon-12 has been completely revised in the light of new experimental data." J. A. Beattie, USA

3773. Valley, L. M., and Legvold, S., Vibrational relaxation times for gas mixtures, *Physics of Fluids* **3,** 5, p. 831 (Letters to the Editor), Sept./Oct. 1960.

It is the purpose of this note to derive a relationship for the vibrational relaxation times of gas mixtures which exhibit single dispersion of sound and to test this relationship against available data. From authors' summary

3774. Sakurai, T., and Baba, T., Surface chemical behavior of polar compounds in nonaqueous liquids; Dispersing effect of the soap solution, *Wear* **3,** 4, 286–296, July/Aug. 1960.

A study has been made of the surface chemical behavior of fatty acid-hydrocarbon solutions in which a steel plate is dipped or iron powder immersed and which is heated to 100 °C. The amount of iron soap formed in the solution gradually increased with the lapse of time. Even when the concentration of fatty acid was greatly changed, the formation of soap was not greatly affected. In the experiments using iron powder, the critical temperature for adsorption was still high, even when the concentration of stearic acid in the cetane solution decreased to as little as $4.45 \cdot 10^{-4}$ M.

Rhodamine B was added to the liquid paraffin solution of Al stearate and Fe stearate or the solution in which the iron powder was immersed in order to measure their absorption and fluorescence spectra. It was then observed that the maximum absorption spectrum was 546 mμ, while the maximum fluorescence spectrum was 560 mμ, and further that micelles were formed in these soap solutions.

The critical micelle concentration values for the liquid paraffin solution of Al stearate and Fe stearate measured by a fluorescence spectrum method were $1.05 \cdot 10^{-4}$ M and $4.0 \cdot 10^{-5}$ M respectively. Meanwhile, it was observed that the iron soap concentration of the solution in contact with the iron powder was more than the above concentration after 3 hours. The solution whose concentration had reached the above soap concentration showed a dispersing effect upon iron powder and carbon black. It can therefore be concluded that the metal soap formed in the lubricating oils will serve to disperse worn debris and other solid matter, and that an effective adsorption film can be formed by bringing about the formation of metal soap and so increasing the critical temperature.

From authors' summary

3775. Connolly, J. F., and Kandalic, G. A., Virial coefficients and intermolecular forces of hydrocarbons, *Physics of Fluids* **3,** 3, 463–467, May/June 1960.

The second virial coefficient of the gaseous equation of state is not very sensitive to . . . intermolecular potentials. However, if the molecules are highly asymmetric and if the temperature range is broad, the effect of asymmetry should become apparent. By measuring second virial coefficients of benzene and n-octane at high temperatures, and combining these results with low-temperature values from the literature, the Kihara potential is shown to be superior to that of Lennard-Jones, for nonspherical molecules. The Kihara potential is also applied to the normal paraffins from propane through heptane.

From authors' summary by L. S. Dzung, Switzerland

3776. Hirai, N., and Eyring, H., Bulk viscosity of liquids, *J. Appl. Phys.* **29,** 5, 810–816, May 1958.

3777. Welker, J. E., Comparison of theoretical and experimental values for the effective heat of ablation of ammonium chloride, NASA TN D-553, 13 pp., Nov. 1960.

Thermodynamic properties of ammonium chloride have been obtained and applied to a theoretical analysis of the shielding mechanism which reduces the rate of heat transfer to a body when ablation takes place at the surface. The analysis has considered the mechanism as one in which the material sublimes directly from the solid to the vapor phase. The results of the computation are compared with the experimental results obtained from the Langley 700-kilowatt arc jet. From author's summary

3778. Leon, G. S., and Shank, M. E., Analysis of solar-furnace performance in mechanical testing at extremely high temperatures, *ASME Trans.* **82** A (*J. Engng. Power*), 4, 325–332, Oct. 1960.

The use of the solar furnace for investigating properties of materials has received increased attention. However, such work has been limited to determining physical properties of refractory materials. Analyses of performance related to such work have been confined to investigations of flux distribution and temperature on flat-plate, hemispherical, and cavity receivers at the focal spot. Heat conduction away from the focal spot usually has not been considered. The present investigation is concerned with the analysis of fluxes and temperatures that can be attained in tensile specimens undergoing mechanical tests. Account is taken of heat loss by conduction and reradiation. It is shown that (a) attainable temperatures are considerably lower than those reached in flat-plate receivers; (b) with normal low-aperture furnaces (i.e., 60 deg), a large furnace is necessary to reach high temperatures with adequately large specimens; and (c) furnaces best adapted to mechanical testing would have larger apertures (120 deg) than are now commonly conceived.

From authors' summary by J. T. Bevans, USA

3779. Brock, F. H., Estimation of specific heats at normal temperatures, *ARS J.* **31,** 2, 265–268 (Tech. Notes), Feb. 1961.

A model of wide applicability has been developed for the calculation of the specific heats at constant volume of solids and liquids at or near normal temperatures. By means of simple computations based on a set of self-consistent rules, the specific heats at constant pressure of compounds of such diverse nature as sodium chloride and quinoline may be estimated generally to within 10 per cent. The approach is based on the postulate that the vibrational energies of a molecule's "groups," as defined in this paper, are negligible compared with their translational and rotational energies.

This method is able to: Differentiate between ionic and covalent compounds, such as the metallic halides and the corresponding oxides and sulfides; explain the low specific heats of the elements beryllium, boron, carbon (diamond and graphite) and silicon; and offer a correlation between specific heat and molecular structure. From author's summary

3780. McLennan, J. A., Jr., Statistical mechanics of transport in fluids, *Physics of Fluids* **3,** 4, 493–502, July/Aug. 1960.

A discussion is given of a statistical mechanics treatment of transport phenomena in fluids for states near equilibrium such that it is applicable to rapidly varying phenomena. The discussion is based upon the introduction of the external nonconservative forces arising from the interaction between a system and its surroundings If these are included in the Liouville equation one is led to an ensemble characteristic of the nonequilibrium state. The theory is not applied to any specific problem in this paper.

D. Ter Haar, England

3781. Marlow, R., Peltier cooling of electrical components in telemetering packages, *ARS J.* **31,** 2, 263–265 (Tech. Notes), Feb. 1961.

Peltier cooling, a direct method of converting electrical energy into usable thermal energy by use of a semiconductor device, is a method of obtaining an adequate thermal environment inside the telemetry package of missiles and satellites. An example of how Peltier cooling may be applied to telemetry packages is discussed.

From author's summary

3782. Taylor, P. F., and Wood, C., Thermoelectric properties of Ag_2Te, *J. Appl. Phys.* **32,** 1, 1–3, Jan. 1961.

The Seebeck coefficient α, electrical conductivity σ, and thermal conductivity K data are given for a number of Ag_2Te specimens measured at room temperature. The maximum value observed for the figure of merit $\alpha^2\sigma/K$ was 1.3×10^{-3} °C^{-1}. The relationship between K and σ was linear, and K_{el} could be expressed approximately by $(\pi^2/3)(k/e)^2\sigma T$. K_{ph} was found to be 0.72×10^{-3} w cm^{-1} °C^{-1}. There was no evidence of an ambipolar diffusion contribution to K. It is suggested that the small energy gap (0.02 ev) previously determined in this compound could account for the absence of a measurable ambipolar diffusion effect, the degeneracylike behavior of K_{el}, and the relatively low values of the Seebeck coefficient. From authors' summary

3783. John, R. S., Field tests of a sonic anemometer-thermometer, *Bull. Amer. Meteorol. Soc.* **41,** 11, 618–626, Nov. 1960.

A sonic anemometer-thermometer system for use at an operational airfield is described. The system provides data on net large-scale surface air movements (wind) and speed of sound (or virtual air temperature) by means of acoustic signals. The measurements are made directly over an operational runway, thus providing data from the actual area of interest. Field tests have shown that the temperature and winds measured over the runway are consistently different from those measured at the usual instrument-shelter locations. Surface wind shifts may occur at one place as much as half an hour prior to shifts at the other location, with dangerous operational conditions resulting. Wind velocities and temperatures measured over the runway by the sonic anemometer-thermometer are more representative of runway operational conditions than the measurements made by any combination of conventional instruments placed off the runway.

From author's summary

Heat and Mass Transfer

(See also Revs. 3442, 3593, 3661, 3673, 3680, 3690, 3691, 3692, 3702, 3703, 3707, 3759, 3849, 3863, 3903, 3924, 3925)

3784. Arpaci, V. S., Transient conduction in coaxial cylinders with relative motion and heat generation, *ASME Trans.* **82** E (*J. Appl. Mech.*), 4, 623–628, Dec. 1960.

Transient temperatures in a coaxially moving tube and a stationary rod resulting from a step change in the rate of energy generation within the rod are obtained. Hankel transforms are used to obtain solutions for small values of time. The classical Laplace transform approach is used for large values of time. The problem is related to that of cooling a nuclear heated rod with a low Prandtl number fluid flowing coaxially to the rod.

J. G. Bartas, USA

3785. Przemieniecki, J. S., Design charts for transient temperature and thermal stress distributions in thermally thick plates, *Aero. Quart.* **11,** 3, 269–284, Aug. 1960.

A set of design charts is presented for the calculation of transient temperature and thermal stress distributions in thermally thick plates subjected to aerodynamic heating.

The method is particularly useful for determining temperatures and thermal stresses in plates with an arbitrary variation of the heat-transfer coefficient and the adiabatic wall temperature of the boundary layer. The present method is based on repetitive applications of the exact analytical solution to a unit triangular variation of the adiabatic wall temperature and a constant heat-transfer coefficient. The actual variation of the adiabatic wall temperature is represented as a series of straight lines while the heat-transfer coefficient is approximated by a step function. The temperature distribution through the plate is separated into linear and "self-equilibrating" temperature distributions to facilitate thermal stress calculations; these distributions can be obtained directly from the design charts presented in the paper.

The general principle of this seminumerical method is also applied to thermally thin plates subjected to arbitrary heating conditions.

From author's summary by S. Lampert, USA

3786. El-Waziri, A. H., The transient temperature distribution within slabs heated in continuous furnaces, *Iron Steel Engr.* **38,** 3, 130–139, Mar. 1961.

Using a mathematical model for the heating process, the method of finite differences for solution of the differential equation of heat flow in two dimensions with boundary conditions dependent on time is applied. The computed temperature histories for a conventional 3-zone furnace are given in graphical form. In this investigation, the heat flow in the steel in the direction of the furnace length is neglected.

Analysis of the results demonstrates the feasibility of improving the degree of temperature uniformity by means other than complete soaking. Two methods are investigated; one involves raising the skid-coolant temperature, and the second involves changes in the geometrical configuration of the skids. Improvement as high as 80 per cent in the degree of temperature uniformity is possible by the use of an alternate skid configuration. The results of this study point the way not only to improvement in temperature uniformity, but also to possible increase in furnace productivity.

From author's summary

3787. Broglio, L., Transient temperatures and thermal vibrations in space structures, AFOSR TN 59-1014 (Universita di Roma, Scuola Ingegneria Aero., SIAR no. 53), 66 pp., June 1959.

In part I, author deals with temperatures and dynamics of heat-sink solids. Green's function is obtained for both the thermal and dynamic situations, and equations are given, the integration of which will give a solution of the thermal vibrations for whatever space and time distribution of temperature is desired. A Green's function is also obtained for the thermal elastic problem. Results in part I show that the complete solution of the conduction problem and of the static and dynamic thermal stresses are obtained by solving two different eigen problems.

Part II considers symmetrical oblations in a hollow sphere for two cases, conductive material and material with zero thermal conductivity. Results are presented for atmospheric oblation in these two cases. Exact and approximate solutions presented vary only slightly from each other.

Part III presents numerical examples such as temperature distribution in a re-entering hemisphere, oblation in a conductive sphere, and thermal elastic displacements due to a step heat source in a infinite solid. J. G. Knudsen, USA

3788. Chernigovskaya, E. I., Thermal waves in a layer and a plate resting on a layer (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk* no. 9, 91–93, Sept. 1958.

A plate of thickness H is placed on an insulating base and its upper face subjected to a periodic heat source. After ingenious but straightforward manipulation (drawing upon an analogy with the uniform beam on an elastic foundation and under tension) the temperature in the plate is found. Continuing, a second plate of thickness b is interposed between the heat source and the first plate, and the solution found again. R. E. Gaskell, USA

3789. Walker, C. L., Matchett, J. D., and Hanold, R. J., Heat storage system for satellite powerplants, *ARS J.* **30,** 10, 979–980 (Tech. Notes), Oct. 1960.

3790. Newcomb, T. P., Temperatures reached in disc brakes, *J. Mech. Engng. Sci.* **2,** 3, 167–177, Sept. 1960.

Theoretical analysis of temperature in disk brakes is based on Laplace transform solution of heat-conduction equation including convective heat transfer at the disk surface. Results are compared with experiments of disk brake on dynamometer test stand, the disk surface temperature being monitored by fast response pyrometer. Theory predicts disk surface temperature within 15%. Author discusses effect of disk thickness, convective and radiative cooling, relative heat flux to disk and pads, and effect of repeated brake application. He compares disk with drum brakes for automobile use. E. G. Chilton, USA

3791. Toga, M., A method of measuring thermal conductivity by revolving ring, *Bull. JSME* **3,** 11, 346–352, Aug. 1960.

A transient method measuring the thermal conductivity of a metal was studied. A wire ring was heated by a stationary spot heat source while the ring was revolved at a constant velocity. The theory was developed and data were reported for copper and mild steel. W. L. Sibbitt, USA

3792. Vodicka, V., Steady temperature field in a composite doubly infinite strip, *J. Phys. Soc. Japan* **15,** 7, 1332–1336, July 1960.

Author discusses two-dimensional steady heat flow in an infinite parallel strip consisting of n bands of arbitrary widths and diffusivities, with perfect contact between bands and prescribed space-dependent temperatures along outer edges. Formal solution by Fourier transform is expressed with aid of matrices.

Solution is checked for $n = 1$ and expressed as inverse transform for $n = 2$, but even here final analytic evaluation found is prohibitively difficult, except when bands have equal width.

S. Paterson, Scotland

3793. Adler, G., Countercurrent cooling of particulate solids (in Hungarian), *Energia es Atomtechnika* **13,** 6, 448–452, June 1960.

Author develops an analytical solution for the heat-transfer problem of a bed of particulate solids cooled by a fluid at countercurrent flow. The solids are assumed to have a finite (rather than infinite) thermal diffusivity; the flow is assumed to be unidirectional, such as would take place in small diameter packed beds.

Closed form solutions are presented for the temperature of the solids and fluid at any point along the pipe, as functions of the properties of solid and fluid, the solid particle size, fluid flow velocity and initial (entry and exit) temperature conditions. The special case of a bed of spherical solids is treated separately and conclusions are drawn for the heat exchanger tube lengths required at specific values of heat duty. N. A. Weil, USA

3794. Morton, B. R., Weak thermal vortex rings, *J. Fluid Mech.* **9,** 1, 107–118, Sept. 1960.

Paper considers weak thermal vortex rings produced by rapid release of heat at point in unbounded fluid. Similarity solution is sought in terms of usual diffusion parameter $r/(2Kt)^{\frac{1}{2}}$, where $r =$

distance from source, t = time and K = thermometric conductivity, and expansion made in powers of an effective Rayleigh number. Temperature distribution is found to decrease outward from center in all directions, with no accumulation of heat in the vortex ring itself.

N. Curle, England

3795. Koh, J. C. Y., and Hartnett, J. P., Measured pressure distribution and local heat transfer rates for flow over concave hemispheres, *ARS J.* **31,** 1, 71–75, Jan. 1961.

The use of parachutes for recovery of equipment from very high velocity vehicles, such as missiles, has directed attention to the need for aerodynamic and heat-transfer information associated with such high drag bodies. With this application in mind, a solid concave hemisphere, positioned in a subsonic flow, was studied. Plexiglas models were placed in water and in air streams, and by using straightforward flow visualization techniques it was determined that the flow in the cup was, in essence, a separate flow region. Quantitative measurements were made of the pressure distribution and local heat-transfer rate over a Reynolds number range of 6000 to 89,000. The pressure on the inner surface of the hemisphere was found to be equal to the total pressure from the stagnation point to an angle of 75 deg, dropping somewhat at greater angles. The heat transfer was found to increase monotonically from the stagnation point to the edge. The over-all dimensionless heat transfer may be given in the form $Nu_D/(Re_D)^{1/4} = 0.42$.

From authors' summary

3796. Secondary heat transfer, *Engineering* **190,** 4937, 755–756, Dec. 1960.

3797. Illingworth, C. R., A note on fluctuating heat transfer at small Peclet numbers, *J. Fluid Mech.* **7,** 3, 442–448, Mar. 1960.

Author analyzes flow past a cylinder and a sphere at Reynolds numbers of the order of 1 or lower, with small temperature differences so flow may be considered incompressible. In this case the approximate energy equation is not linked with the equations of continuity and momentum, and may be solved without the velocity field. The solutions for the temperature field of a warm circular cylinder or sphere held at rest in a fluctuating stream are given.

For the sphere, the steady-state Nusselt number equals half the Peclet number. For the cylinder it ranges from 0.123 at Peclet = 0.08 to 1.877 at 1.6. For both cases, the coefficients to yield the amplitude and phase lag of the fluctuating response are tabulated.

C. F. Bonilla, USA

3798. Agrawal, H. C., Heat transfer in laminar flow between parallel plates at small Peclet numbers, *Appl. Scient. Res.* (*A*) **9,** 2/3, 177–189, 1960.

Author considers a viscous, incompressible, heat-conducting fluid flowing between two infinite parallel boundary walls $y = \pm l$, $x \leqslant 0$ and $y = \pm l$, $x \geqslant 0$. The temperature of the walls on the left of the origin is T_0 and that on the right is T_s, the fluid temperatures at any point being T_1 and T_2 respectively (T_0 and T_s constant).

The problem of heat transfer is studied taking into account the effect of heat diffusion on the incident fluid; that is by obtaining solutions of the energy equation for $x \leqslant 0$ and $x \geqslant 0$ and by imposing continuity conditions on the temperature and its derivative at the junction $x = 0$.

At small Peclēt numbers the incident temperature is affected by the diffusion of heat from the region $x > 0$ to the region $x < 0$.

A. Pignedoli, Italy

3799. Clarke, J. F., Heat conduction through a gas with one inert internal mode, Coll. Aero. Cranfield, Note 102, 30 pp., May 1960.

The mode of heat transfer of molecular rotational energy and atomic vibrational energy is at present little understood. The relaxation times for vibrational modes for nonpolar molecules have not been extensively investigated and the details of wall interaction in heat transfer are little understood. Author has considered the simplified case of a single internal atomic vibration for a polyatomic molecule in a steady state of heat conduction. He assumes the rotational energy to be in equilibrium with the translational modes and makes use of the relaxation time for the vibrational mode to evaluate the deviation of the thermal conductivity from complete equilibrium. The results obtained are of interest and the discussion illuminating.

F. G. Keyes, USA

3800. Vargaftik, N. B., and Tarzimanov, A. A., An experimental investigation into heat conductance of water vapor (in Russian), *Teploenergetika* no. 7, 12–16, July 1960.

The results are given of the experimental investigation into heat conductance of water vapor at the temperatures from 320 to 560 °C and under pressures from 5 to 500 kg/cm.

From authors' summary

3801. Longuet-Higgins, M. S., Mass transport in the boundary layer at a free oscillating surface, *J. Fluid Mech.* **8,** 2, 293–306, June 1960.

In an earlier paper [AMR 6(1953), Rev. 3782] author calculated the vertical gradient of the mass-transport velocity just below the boundary layer at the surface of sinusoidal gravity waves. Experiments are described in the present paper which confirm author's result, which is exactly twice that given by Stokes's irrotational theory. Many precautions were necessary in order to reproduce conditions of the theory. In particular, care was taken that observations were made after vorticity had diffused by viscous conduction to a sufficient depth below the surface boundary layer, but before vorticity could be carried by convection from the ends of the wave tank.

J. N. Hunt, England

3802. Kubota, T., Ablation with ice model at M = 5.8, *ARS J.* **30,** 12, 1164–1169, Dec. 1960.

The possibility of an experimental study of aerodynamic ablation in moderate-temperature wind tunnels is examined on the basis of available laminar boundary theories. The results indicate that such experiments may yield basic results useful for the understanding of aerodynamic ablation. With such materials as water ice, dry ice, naphthalene and camphor, a fairly wide range of important parameters of ablation phenomenon may be covered. An experiment was performed with a water ice, hemisphere-cylinder model in the GALCIT $M = 5.8$ wind tunnel at a supply temperature of 300 F, and the results show: That the ice melted around the stagnation point when the supply pressure was above 34 psia, and the ice sublimed everywhere on the model when the pressure was less than 34 psia; and that the rates of ablation heat transfer were 0.69 ±0.11 cal per cm² sec at the stagnation point, and from 0.15 to 0.03 cal per cm² sec on the cylindrical afterbody. These experimental results compare favorably with theoretical predictions.

From author's summary

3803. Hansen, C. F., Heat diffusion in gases, including effects of chemical reaction, *ARS J.* **30,** 10, 942–946, Oct. 1960.

Heat diffusion in gases, especially as related to heat transfer in stagnation region of blunt hypersonic bodies, is treated with simplifying assumptions giving better physical picture of phenomena. Results agree reasonably well with available experimental data as well as with more rigorous calculations. Since coefficient of thermal conductivity must be taken as function of temperature, dependent variable is taken as integral of product of thermal conductivity and temperature over a temperature range

(called heat flux potential, since its gradient at any point is the heat flux). Heat diffusion equation can then be expressed in rather simple form capable of numerical integration. Article is of interest as giving simple, understandable treatment applicable to gases in general, though excluding effects of mass convection and radiation. C. W. Smith, USA

3804. Niu, K., Flow of a condensing vapour with heat exchange, *J. Phys. Soc. Japan* **15,** 6, 1108–1112, June 1960.

3805. Thal-Larsen, H., Dynamics of heat exchangers and their models, *ASME Trans.* **82D** (*J. Basic Engng.*), 2, 489–504, June 1960.

Author introduces a novel and probably very useful approach to heat-exchanger dynamics. In his own words, "The author rejects, momentarily, actual experimentation with real heat exchangers for logical cogitation and arm-chair experiments."

Author obtains approximate transfer functions for various heat-exchanger configurations by obtaining, in a simple manner, the response to a suitably selected impulse in the temperature of one of the fluids. He then compares the frequency response of his simplified system with the frequency responses reported in the literature for similar heat exchangers. The agreement is, in general, satisfying.

Reviewer feels the method could be very useful to engineers concerned with heat-exchanger dynamics, but thinks, as did many of the discussers of the paper, that care and experience are necessary for the proper selection of suitable models for the transfer functions. The concept of normalized time and normalized frequency for the classification of heat exchangers should be useful in the correlation of data from various sources.

W. A. Wolfe, Canada

3806. Hiester, N. K., and De La Rue, R. E., The image furnace as a research tool, *ARS J.* **30,** 10, 928–938, Oct. 1960.

3807. van Gunst, E., Physical aspects of the heat exchange between the human body and its surrounding, especially by radiation, *Ingenieur* **72,** 49, G.61–G.71, Dec. 1960.

The paper gives a survey of the physical principles of the heat exchange of the human body: convection, evaporation, radiation.

In several industrial processes the human body has to be protected against comparatively heavy heat radiation from heat sources. Methods for evaluating the heat quantities and their distribution over the human body must be available both in the design of new processes and in existing situations which need correction. For designing purposes there is a need for calculation techniques; for studying situations under working conditions direct measurements can be carried out. These methods have to take into account the configuration factors and the temperature distributions over the heat sources. Measurements have to prove the validity of the available methods of calculation.

The heat exchange by radiation between two surfaces is given by the Stefan-Boltzmann Law

$$Q_{12} = (\varepsilon_1 \varepsilon_2)(f_{A_1 A_2} A_1)\sigma\left[\left(\frac{T_1}{100}\right)^4 - \left(\frac{T_2}{100}\right)^4\right]$$

For purposes of evaluation, information must be available of the emission capacities, the configuration factor and the temperatures of the surfaces. If the two surfaces are irregularly shaped, calculation of the configuration factor from available graphs and tables is highly complicated and time-consuming. A method has been developed for measuring the configuration factor from a point to a surface. From that point a photograph can be taken of the surface. This photograph can be integrated by an integrator with the factor as result. From authors' summary

3808. Saltzman, A. R., Thermal application of catalytic chemical kinetic theory, *Aero/Space Engng.* **19,** 6, 28–31, 37, June 1960.

Author reviews principles of catalytic chemical kinetic theory with regard to their use in the thermal design of avionics equipment. Either endothermic or exothermic reactions may be employed in a reactor, depending on the temperature condition desired.

The catalyst may be chosen to cause a specific reaction to take place, as well as to increase the rate at which a given reaction occurs. Some general reactor design relations are reviewed, specifically for a homogeneous second-order chemical reaction at constant temperature and pressure. Some confusion is introduced by the author's erroneous conclusion that since the concentration of a constituent may vary due to changes in volume occupied by a unit mass in a constant pressure flow field, it is necessary to write the equations involving reactions in a flow system in terms of partial pressures rather than concentrations.

T. C. Adamson, Jr., USA

Combustion

(See Revs. 3808, 3809, 3875, 3880, 3881, 3885, 3893)

Prime Movers and Propulsion Devices

(See also Revs. 3449, 3518, 3740, 3746, 3789, 3867, 3875, 3878, 3879, 3883, 3893, 3939)

3809. Livesey, J. L., Jones, P. K., Parker, E., and Shaw, J. P., Aerodynamics of tube-type gas-turbine combustion chamber entry sections, *J. Mech. Engng. Sci.* **2,** 3, 202–226, Sept. 1960.

Paper presents over-all results of measurements of total pressure loss and velocity distribution for the secondary air flow in a combustor entry section, as affected by variations in entry geometry, primary-to-total-mass flow ratio and entry velocity distribution. Various aerodynamic losses, assumed discrete, are given as functions of simple geometrical and aerodynamic ratios. Design considerations are emphasized. R. A. Gross, USA

3810. Kadirov, N. B., The derivation of the fundamental differential equations determining the working cycle of oilfield compressors of the reciprocating type (in Russian), *Izv. Vyssh. Uchebn. Zavedenii. Neft' i Gaz.* no. 4, 105–114, 1958; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3730.

A system of differential equations is examined, determining the processes taking place inside the cylinder as well as the process of outflow of the gases through the open valves and through the leaks in the cylinder of a reciprocating compressive. The concrete values of the gravimetric gas flow through the gap of an open valve, the gas losses through the cylinder leaks, and the quantity of heat withdrawn from the gas by heat exchange between the gas and the cylinder walls are determined. V. N. Gusev

Courtesy Referativnyi Zhurnal, USSR

3811. Watanabe, I., Nakada, T., and Ando, T., Effect of exhaust pipe system upon the performance characteristics of a two-cycle diesel engine: Part 1, The influence of exhaust pipe length, *Bull. JSME* **3,** 12, 532–539, Nov. 1960.

This paper deals with the influence of the exhaust pipe length upon the performance characteristics of a two-cycle diesel engine. The two-cycle uniflow scavenged three-cylinder diesel engine was employed, and the length of each exhaust pipe was changed from 20 cm to 420 cm.

The following results were obtained.

(1) The optimum performance was obtained at the following pulsation coefficients q, i.e. $q = 0.24$, 0.70 and 1.16, q being defined as $q = nL/15\,c$, where n = crankshaft revolutions per minute, L length of the exhaust pipe and c sonic velocity in the exhaust pipe.

(2) Theoretical treatment performed by one of the present authors showed fair coincidence with the experimental results.

(3) The difference of output developed by the engine at good tuning and that at poor tuning was about 15%.

(4) In the practical application of the present results, especially to the variable speed engines, a shorter optimum exhaust pipe length is preferable to the longer one.

From authors' summary

3812. Hrubecky, H. F., Free turbine systems in rotary wing aircraft, *Aerospace Engng.* **20,** 1, 10–13, Jan. 1961.

A comparison of four different power-plant systems incorporating a free turbine, as applied to rotary wing aircraft. Considered were the ratio of free turbine shaft horsepower to primary gas flow rate; main compressor-turbine shaft horsepower; specific fuel consumption; airflow ratio; and the duct pressure and temperature.

From author's summary

3813. Baldwin, B. S., Jr., An optimization study of effects on aircraft performance of various forms of heat addition, NASA TN D–74, 48 pp., Mar. 1960.

Author's summary states: "Basic ramjet aircraft design considerations are reviewed at a level of simplification appropriate for evaluation of external heat-addition schemes. No definite conclusions are given as to the relative advantage of external combustion in comparison with conventional ramjet combustion because of the incompleteness of the knowledge of both at hypersonic speeds. Instead, similarity parameters are derived which will allow a ready comparison when complete data become available. Possible variations of quantities, such as wing size relative to engine size, which would affect the comparison are eliminated from consideration by deriving the optimum values."

General conclusions of this parametric study are interesting and reviewer believes them to be qualitatively correct. As author states, actual comparisons of merits of external heat addition will depend strongly on configurations and missions as well as ability to supply required efficiency terms from future experimental data for high flight speeds. Reviewer believes that, for speeds above 10,000 ft/sec, (a) the stoichiometric limitation on fuel rate should be lifted, and (b) the effect of centrifugal lift should be included, because external heat addition may supply more lift than desired, thus requiring counteracting drag.

G. L. Dugger, USA

3814. Moutet, A., and Barrere, M., Lithergolic or hybrid rockets (in French), *Rech. Aéro.* no. 75, 23–35, Mar./Apr. 1960.

Theoretical and experimental results describing the operation of hybrid, liquid-solid propellant rockets are presented. Motor types are discussed in terms of different combinations of liquid and solid fuels and oxidizers. Stability limits and mission optimization dictate the choice of type. Three hybrid configurations are shown, and an approximate analysis of conditions in one of the configurations is carried out. The velocity of regression at the solid surface is assumed proportional to the αth power of pressure, the βth power of mass flux through the grain, and the yth power of characteristic velocity.

Experiments were carried out with the configuration subjected to analysis. Nitric acid was injected axially through a plastic grain of unreported composition which is hypergolic with nitric acid. Injection pressure, chamber pressure, and acid flow were measured. After combustion was extinguished at the end of each run, the weight loss of the solid was determined to find the mean total mass flow. Grain and injector geometrical properties were varied from run to run. Experimental results could be fitted with the simple theory with α equal to 0.24 or 0.34 depending on conditions (which were unspecified) and $\beta \sim 1/2$. The nature of the experiment evidently prevented an independent determination of y.

A. Q. Eschenroeder, USA

3815. Bergman, K. L., Simplified analysis of a thrust-augmentation system, *ASME Trans.* **82** E (*J. Appl. Mech.*), 2, 358–359 (Brief Notes), June 1960.

3816. Brewer, G. D., and Levin, E., Structural weight approximation for a bell-nozzle divergent section, *ASME Trans.* **82** B (*J. Engng. Industry*), 4, 359–362, Nov. 1960.

In the preliminary design of missile systems it is necessary to consider the weight of the individual components which comprise the missile. The usual procedure in weight approximation is to consider that an article is composed of small regular-shaped bits, each of whose weights is easily found and whose sum approximates the weight of the total article. When the component is such an irregular shape that a simple approximation cannot be made, or where the number of digital operations is excessive, the estimation of its weight becomes a tedious procedure. In this report, a method is derived for approximating the structural weight of such an article, namely, the divergent section of a bell-shaped nozzle for a rocket motor.

From authors' summary

3817. Knuth, E. L., Optimum contours for propulsion nozzles, *ARS J.* **30,** 10, 983–984 (Tech. Notes), Oct. 1960.

3818. Resler, E. L., Jr., and Rott, N., Rocket propulsion with nuclear power, *ARS J.* **30,** 11, 1099–1101 (Tech. Notes), Nov. 1960.

Magneto-fluid-dynamics

(See also Rev. 3876)

3819. Lyubarskii, G. Ya., and Polovin, R. V., The piston problem in magnetohydrodynamics, *Soviet Phys.–Doklady* **4,** 5, 977–980, Mar./Apr. 1960. (Translation of *Dokladi Akad. Nauk SSSR (N.S.)* **128,** 4, 684–687, Sept./Oct. 1959 by Amer. Inst. Phys., Inc., New York, N.Y.)

Paper examines in a qualitative mathematical way the steady motion of a piston into a compressible, perfectly conducting medium bearing a magnetic field. Sketch is given of a proof that only two variants exist, viz., fast and slow magnetoacoustic shock waves when the piston moves into the fluid, and fast and slow self-similar waves when it is withdrawn. The Alfvén wave is absent in both cases. At various stages in the proof results are adduced from earlier papers. Of the thirteen references all but one are to the Russian literature. Of these, six are available in translation.

F. D. Bennett, USA

3820. Collins, W. D., On the solution of some axisymmetric boundary value problems by means of integral equations, Part 1: Some electrostatic and hydrodynamic problems for a spherical cap, *Quart. J. Mech. Appl. Math.* **12,** 2, 232–241, May 1959.

The stream function for uniform motion of a fluid past the cap was derived from a specified stream function on the cap. The couple required to maintain the slow steady-state rotation of a spherical cap in a viscous fluid was developed.

W. L. Sibbitt, USA

3821. Wu, C. -S., Hypersonic viscous flow near the stagnation point in the presence of magnetic field, *J. Aerospace Sci.* **27,** 12, 882–893, 950, Dec. 1960.

Paper investigates the hypersonic viscous flow past blunt-nosed bodies with hydromagnetic interaction. Local similarity solutions of flow field and temperature distribution are near the stagnation-point region. The discussions may be grouped into two parts: two-dimensional problem (circular cylinder) and axisymmetric problem (sphere). Numerical computations have been carried out for the sphere problem for the viscous-layer regime, with various magnetic field strengths and electrical conductivities.

From author's summary by G. Sestini, Italy

3822. Ando, S., General theory of electrically conducting perfect gas flow past a three-dimensional thin body, *J. Phys. Soc. Japan* **15,** 1, 157–167, Jan. 1960.

General theory of electrically conducting gas past a three-dimensional thin body is presented. Fundamental equation for a parametric function is derived. The magnetic field, velocity and pressure are all connected to a parametric function, and so the boundary conditions for the fundamental equation can be written explicitly. The flow over a wavy wall is treated as an application of the present theory in which the applied magnetic field may be in an arbitrary direction.

From author's summary by U. H. Kuo, China

3823. Yosinobu, H., A linearized theory of magnetohydrodynamic flow past a fixed body in a parallel magnetic field, *J. Phys. Soc. Japan* **15,** 1, 175–188, Jan. 1960.

Paper deals with the problem of plane, incompressible and electrically conducting fluid past a fixed body with magnetic field parallel to the flow at infinity. Author solves the problem by a method similar to Oseen's approximation and shows that, for finite Reynolds and pressure numbers, flow and magnetic fields can be expressed as superposition of rotational and irrotational fields. Unlike the case of non-conducting fluid, vortices diffuse either up- and downstream or downstream only according as the pressure number ($= a^2/V^2$, here a being the speed of Alfvén wave; V the free-stream velocity) is greater or less than unity. When $a = V$, the method of perturbation breaks down with the appearance of a singularity. Detailed calculations are carried out for a circular cylinder. For small Reynolds and magnetic Reynolds numbers, an expression for drag is obtained and behaves as $1/\ln|a - V|$ near $a = V$.

Y. H. Kuo, China

3824. Gotoh, K., Magnetohydrodynamic flow past a sphere, *J. Phys. Soc. Japan* **15,** 1, 189–196, Jan. 1960.

Problem is solved by the same method as that of the preceding paper by Hirow Yosinobu. For this case, drag coefficient is also singular at $a = V$ but is continuous and nonvanishing there.

Y. H. Kuo, China

3825. Lur'ev, I. M., On a solution to the equations of magnetogasdynamics, *Appl. Math. Mech. (Prikl. Mat. Mekh.)* **24,** 1, 233–237, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N.Y.)

In this note the equations of plane, steady magnetohydrodynamics for a compressible, inviscid fluid having an infinite electrical conductivity are studied. As a consequence of these assumptions the magnetic field is congruent with the velocity field [see Sears and Resler, *J. Fluid Mech.* **5,** 2, 257–273, Feb. 1959]. After separating the vector fields into rotational and irrotational parts, it is shown that by virtue of the assumption of plane flow, the governing equations for the rotational fields can be transformed into a linear Chaplygin type of differential equation. Solutions for this equation are known in some cases.

Since it appears difficult to express the boundary conditions in the transformed coordinates it is the opinion of the author that while the note may be of theoretical consequence in classifying types of flow there seems to be no immediate practical application of this solution.

E. E. Covert, USA

3826. Kaliski, S., Solution of the equations of motion of an isotropic conductor in a magnetic field (in English), *Arch. Mech. Stos.* **12,** 2, 229–239, 1960.

Linearized conjugate Lamé and Maxwell equations are considered for an infinite isotropic elastic and anelastic body in a magnetic field, assuming finite electric conductivity. Formal solution is obtained by reduction to a substitute boundary problem proposed previously by the author (if the region of action of the excitation forces or initial perturbations is finite). The solution reduces to a system of nine algebraic equations with nine unknowns.

H. Zorski, Poland

3827. Kogan, M. N., On the uniqueness of quasihyperbolic magnetohydrodynamic flows, *Appl. Math. Mech. (Prikl. Mat. Mech.)* **24,** 2, 530–533, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N.Y.)

3828. Tkalich, V. S., Investigation of the system of magnetohydrodynamic equations in the two-parameter case (in Russian), *Izv. Akad. Nauk SSSR, Otd. Tekh. Nauk, MiM* no. 1, 182–183, 1960. (Translated by Morris D. Friedman, Inc., P. O. Box 35, W. Newton, Mass., Pap. T-145, 4 pp.)

Paper describes method of generating solutions for steady flows of incompressible, inviscid fluid conductors. Solutions are referred to arbitrary orthogonal coordinates and all variables are independent of one coordinate. Some degenerate simple cases are considered briefly. There is no discussion of the solutions from a physical or application standpoint.

J. A. Shercliff, USA

3829. Carini, G., Energy considerations in magnetohydrodynamics (in Italian), *Atti Accad. Naz. Lincei, R.C. Cl. Sci. Fis. Mat. Nat.* **27,** 1/2, 48–53, July/Aug. 1959.

Derivation of energy equations for the magnetohydrodynamic consideration governed by the Navier-Possion and Minkowski equations. Three concepts of pressure are discussed: The hydrodynamics pressure, the electromagnetic pressure and a pressure of mixed nature.

Also, the energy equation in an adiabatic process taking place in a perfect fluid with infinite conductivity is considered.

S. Eskinazi, USA

3830. Ong, R. S., and Nicholls, J. A., On the flow of a hydromagnetic fluid near an oscillating flat plate, *J. Aero/space Sci.* **26,** 5, 313–314 (Readers' Forum), May 1959.

3831. Jackson, J. L., Electric field distribution in a dense plasma, *Physics of Fluids* **3,** 6, 927–931, Nov./Dec. 1960.

A calculation is presented of the probability distribution function of the electric field at the center of an ion or atom in a plasma in the high ion-density limit. In this limit, it is possible to take into account rigorously the effect of the Coulomb interactions on the distribution function. The distribution function in the high-density limit is Gaussian. The Coulomb interaction decreases the mean square electric field by the multiplicative factor $[1 + \kappa a_0 + \frac{1}{3}(\kappa a_0)^2]^{-1}$, where κ is the reciprocal Debye length and a_0 the radius of the ion or atom at whose center the field is evaluated.

From author's summary

3832. Rosenbluth, M. N., Long-wavelength beam instability, *Physics of Fluids* **3,** 6, 932–936, Nov./Dec. 1960.

The kinematics of a self-pinched neutralized relativistic stream is developed in the limit of oscillations whose frequency in the

rest frame of the beam is low compared to the betatron frequency of oscillation of the particles of the beam. It is shown that in this limit the beam is able to displace itself more or less rigidly, giving rise to the possibility of kink-type instabilities depending on its coupling with the external medium. In particular, the case where the beam passes through a low conductivity plasma is considered. In this case there is a viscous drag when the beam displaces and pulls its magnetic field through the resistive plasma. This leads to an instability of the beam.

From author's summary

3833. Tsytovich, V. N., On the influence of resonance properties of a plasma on electro-acoustic wave propagation (in Russian), *Vestnik, Moscow Univ., MMAFKb Ser.* **14**, 2, 135–141, 1959. (Translation by Morris D. Friedman, Inc., P. O. Box 35, W. Newton, Mass., Pap. T-139, 8 pp.)

3834. Dodo, T., Heating of a plasma by acoustic waves, *J. Phys. Soc. Japan* **15**, 7, 1292–1296, July 1960.

Author proposes to exploit the high dissipation rate of acoustic waves in plasmas. The flow of heat from the high-temperature compression region toward a lower-temperature expansion region is the irreversible process that is enhanced by the high thermal conductivity of the plasmas. A rather optimistic numerical example is also given both for standing waves and traveling waves.

L. S. G. Kovasznay, USA

3835. Bernstein, W., Kranz, A. Z., and Tenney, F., Kinematics of ohmic heated plasmas in the B-1 stellarator, *Physics of Fluids* **3**, 6, 1019–1025, Nov./ Dec. 1960.

A kinematic description of the B-1 stellarator plasma during various stages of ohmic heating discharges is presented. It is shown that for specific ranges of plasma current, for a given confining field, the plasma assumes a shape which has an azimuthal distribution of the form $\exp im\theta$. It is further shown that the plasma column rotates at high velocity while the distortion is present. The possible relationship between these current ranges and the predictions of hydromagnetic instability theory is considered.

From authors' summary

3836. Banister, J. R., Separation of magnetic driving and ohmic heating, *Physics of Fluids* **3**, 4, 648–655, July/Aug. 1960.

In this mostly experimental study, nitrogen plasma is being impulsively generated in an "impulse tube" by a linear nonoscillatory discharge of a condenser through electrodes in a steady, magnetic field. As long as the condition of impulsiveness is satisfied (i.e. the gas does not move further than the width of the electrodes during the discharge process), a simple adaptation of shock-tube theory successfully correlates experimental results for initial pressures in excess of 0.2 mm Hg. The method allows conceptual distinction between the energies due to magnetic driving and ohmic heating which in turn permits determination of temperature and electrical conductivity of the gas. The only observed quantity being shock speed, a surprising number of useful results have been deduced.

P. Savic, Canada

3837. Coensgen, F. H., Sherman, A. E., Nexsen, W. E., and Cummins, W. F., Plasma injection into a magnetic field of cusped geometry, *Physics of Fluids* **3**, 5, 764–768, Sept./Oct. 1960.

A plasma stream was directed from a field-free region along the axis of symmetry into a magnetic field of biconical cusped geometry. No evidence was found to support the hypothesis that a directed plasma stream can not penetrate a magnetic field whose value exceeds $B_c^2 = 12\pi\rho v^2$, where ρ is the plasma density and v its directed velocity. As the plasma penetrated the magnetic field, the plasma and field were found to intermix. Large quantities of the plasma which entered the containment region through one point cusp were found to leave promptly through the second point cusp and through the line cusp. Bombardment of the vacuum chamber walls in the vicinity of the line cusp generated sufficient secondary ions to mask any small-scale plasma trapping. However, there was no evidence of gross trapping of the injected plasma.

From authors' summary

3838. Pain, H. J., and Smy, P. R., The electrical conductivity of shock-ionized argon, *J. Fluid Mech.* **9**, 3, 390–400, Nov. 1960.

The electrical conductivity of shock-ionized argon has been measured at temperatures between 6000 K and 13,000 K and electron number densities in the range 10^{16} to 10^{18} cm^{-3}. The results are compared with theoretically computed values and show sufficient agreement to be plotted on a linear scale. The experimental technique is based on the measurement of voltages generated in a search coil by the flux from currents induced in a plasma moving rapidly through a magnetic field.

From authors' summary

3839. Vali, V., and Turner, T. E., Attenuation of a moving magnetic field in a shock tube, *Physics of Fluids* **3**, 6, 1029–1031, Nov./Dec. 1960.

3840. Rand, S., Damping of the satellite wake in the ionosphere, *Physics of Fluids* **3**, 4, 588–599, July/Aug. 1960.

Landau damping of the ion plasma oscillations which constitute the wake of a line charge moving supersonically through a low-density plasma is studied. Maxwellian distribution functions in the ambient plasma for both electrons and ions have been assumed. It is found that, unless the electron temperature is at least an order of magnitude greater than the ion temperature, the wake begins to damp after about a Mach number of Debye lengths behind the line charge. After the damping begins, the wake decreases quadratically with distance behind the charge.

As the ratio of electron to ion temperatures increases above a value of about ten, the damping rapidly becomes unimportant.

For the same total charge of the body a larger body produces a less intense wake.

From author's summary by W. Fiszdon, Poland

3841. Ericson, W. B., and Bazer, J., On certain properties of hydromagnetic shocks, *Physics of Fluids* **3**, 4, 631–640, July/Aug. 1960.

Proofs of four basic properties of stationary, planar, nonrelativistic hydromagnetic shocks are presented. These properties are: (1) the specific entropy behind a hydromagnetic shock exceeds that ahead, if, and only if, the shock is compressive; (2) the specific entropy behind a compressive shock varies in the same sense as the mass flux; (3) in the region behind (compressive) fast shocks, the fast disturbance speed is greater than the normally directed fluid velocity relative to the shock; (4) in the region behind (compressive) slow shocks, the slow disturbance speed may be less than, equal to, or greater than the normally directed fluid velocity relative to the shock. The equality holds when the specific entropy and the mass flux assume their maximum values.

From authors' summary by D. Y. Hsieh, USA

3842. Ellis, R. A., Jr., Goldberg, L. P., and Gorman, J. G., Possibility of an electrostatic instability in a stellarator, *Physics of Fluids* **3**, 5, 797–799, Sept./Oct. 1960.

At certain times during ohmic heating in hydrogen and deuterium discharges in the B-3 stellarator, it was observed that over a wide range of experimental conditions the plasma current decreased abruptly (current inhibition) following a period of increasing cur-

rent and decreasing charged particle density. It is suggested that this may be a manifestation of an electrostatic instability.

From authors' summary

3843. Andrew, A., and Fitzpatrick, J. P., Velocity and impulse of an accelerated plasma, *Physics of Fluids* **4,** 1, 160–161 (Letters to the Editor), Jan. 1961.

3844. Taylor, H. S., Effect of many-body collisions on the rate of thermonuclear reactions, *Physics of Fluids* **3,** 6, 1032–1033 (Letters to the Editor), Nov./Dec. 1960.

3845. Pytte, A., Pinch with a small rotation, *Physics of Fluids* **3,** 6, 1034–1035 (Letters to the Editor), Nov./Dec. 1960.

3846. Stodiek, W., Ellis, R. A., Jr., and Gorman, J. G., Loss of charged particles during ionization in stellarator discharges, *Physics of Fluids* **3,** 6, 1035–1036 (Letters to the Editor), Nov./Dec. 1960.

3847. Alfvén, H., Lindberg, L., and Mitlid, P., Experiments with plasma rings, *J. Nuclear Energy* (Part C. *Plasma Phys., Accelerators, Thermonuclear Res.*) **1,** 3, 116–120, Mar. 1960.

The construction of a coaxial plasma gun is described. At its output end the gun is provided with a radial magnetic field which is trapped in the plasma. The plasma is shot out from the gun and forms a plasma ring which is similar in its basic structure to plasma rings produced in the toroidal pinch experiments. The aim of the experiments was to bring these plasma rings to rest and to study their stability in order to compare the results with those obtained by the more conventional method of the toroidal pinch experiments. In an added note the authors indicate that they succeeded in producing standing rings with life times of 40 μ sec. In the last 20 μ sec after all transients have died out, there exists a free and reasonably stable plasma ring which is independent of all external currents. J. Rabinowicz, Israel

3848. Wetstone, D. M., Ehrlich, M. P., and Finkelstein, D., Experiments on plasmoid motion along magnetic fields, *Physics of Fluids* **3,** 4, 617–630, July/Aug. 1960.

Plasmoids from sources up to 40 joules were projected inside highly evacuated glass tubes along magnetic fields up to 3 Weber/m^2 of various shapes and strength and time-integrated photographs of the recombination light are presented. The copper plasma seemed to follow the field lines reasonably closely for axisymmetric geometries, while in curved fields there was some drift to the walls, probably due to the presence of crossed polarization fields, an effect which was more marked for higher plasma densities. Plasmoid bulk speed, center of mass position and expansion rate were measured with photomultipliers, giving a maximum of 5.5 and 1.9 cm/μ sec, respectively, for the two speeds. From this the maximum ion temperature was deduced as 120 ev for copper. A mechanism is proposed which explains this high figure in terms of shock thermalization. An extension of magnetic mirror theory to a moving maxwellian plasma is used to derive a total reflection coefficient. In the appendix a method of magnetic induction line plotting by computer is explained and a description of the experimental setup is provided. P. Savic, Canada

3849. Kirschner, I., Principle of design of adiabatic magnetic cooling (in Hungarian), *Magyar Fiz. Foly.* **8,** 6, 487–498, June 1960.

3850. Conn, G. L., Electrical conductivity of a partially ionized gas, *Physics of Fluids* **3,** 6, 1031–1032 (Letters to the Editor), Nov./Dec. 1960.

While investigating the energy transfer processes occurring between an electric arc and the surrounding gas, it was found desirable to study in detail the transport properties of species diffusion and thermal flux in a partially ionized monatomic gas in the presence of a magnetic field.

By using the disciplines of irreversible thermodynamics and kinetic theory, equations are derived for the electron and ion motion relative to the mass velocity of the gas.

From author's summary

3851. Ekman, C., Hoh, F. C., and Lehnert, B., Behavior of the positive column in a magnetic field, *Physics of Fluids* **3,** 5, 833–834 (Letters to the Editor), Sept./Oct. 1960.

Aeroelasticity

(See Rev. 3468)

Aeronautics

(See also Revs. 3437, 3448, 3706, 3767, 3819, 3867)

3852. Marinescu, Al., Dynamic stability of convertiplanes in ordinary flight evolutions (in Roumanian), *Studii Si Cercetari Mecan. Appl.* **11,** 4, 835–845, 1960.

Author examines the dynamic stability of two types of convertiplanes, i.e., that with tilting wing and propellers and that with fixed wing. After establishing the equations of the undisturbed motion, he deduces the equations of the longitudinal and lateral disturbed motions. Further, the criteria of dynamics stability are presented and the conditions in which the respective convertiplanes may enjoy dynamic stability are shown.

A. Petre, Roumania

3853. McGowan, W. A., An analysis of incremental horizontal-tail loads measured on a swept-wing bomber airplane in sideslip maneuvers, NASA TN D-100, 34 pp., Oct. 1959.

Paper is an experimental investigation on the incremental horizontal-tail loads due to the rudder-step, aileron-roll and steady side-step maneuvers. The tests were carried out on an aircraft flying at three altitudes (15,000 ft, 25,000 ft and 35,000 ft) and at Mach numbers $0.49 \leqslant M \leqslant 0.82$.

The normal loads and the rolling moments were determined for each half of the horizontal tail with the aid of gage measurements, while the processing of data gave the derivatives of the normal force, rolling moment and pitching moment for the wing-body system, function of the side-slip angle. For this purpose the influence of the rotation velocity about the rolling axis is neglected; it is also assumed that incremental loads due to the side-slip on the two halves of the tail are equal and of contrary sign and the increase of incidence is deduced by calculations.

Approximate expressions are given for the derivatives, as functions of the Mach number and tail sweptback angle, and for the spanwise displacement of the pressure center.

A comparison of experimental and theoretical data showed a fairly good agreement for the derivatives of the asymmetric forces on the tail with respect to the side-slip angle and a 100% difference for the rolling-moment derivatives. On the contrary, the variation of the pitching moment of the wing-body system coincided satisfactorily with the wind-tunnel testing.

Paper represents a useful contribution to the design of subsonic aircraft. The above-mentioned simplifying assumptions are valid in the experimental case examined when the tail is not subjected to the effects of the body wake. Reviewer believes the influence

of the vertical tail is however rather important and the procedure may be justified generally for low values of the lateral side-slip angle ($\Delta\beta \leq 6$), as in the case of author's tests.

N. S. Tipei, Roumania

3854. Ryder, F. L., Anticipating anti-skid system, *Aerospace Engng.* **19,** 11, 24–27, Nov. 1960.

Introductory theory and schematic for continuous maximization of brake torque without danger of skidding.

From author's summary

3855. Patterson, D. W., Sonic boom—limitations on supersonic aircraft operations, *Aero/Space Engng.* **19,** 7, 20–24, 44–45, July 1960.

3856. Price, H. L., The avoidance of ground resonance; exact stability criteria for helicopters on isotropic supports: Parts 1 and 2, *Aircr. Engng.* **32,** 376, 156–160, June 1960; **32,** 377, 195–200, July 1960.

An examination is made of the way in which the ground resonance properties of a helicopter depend on the fuselage damping, blade damping, drag hinge offset, inter-blade spring stiffness, blade mass and angular velocity of the rotor as specified by the parameters λ_f, λ_β, Λ_1, Λ_2, Λ_3 and Ω respectively. A direct method of drawing stability boundaries in the (Ω, λ_β) plane is developed, and the geometry of these boundaries as the remaining parameters vary is studied theoretically at length. Arising out of the geometry, the validity of Coleman's criterion for stability is examined, and it is shown that the requirement that the product $\lambda_f\lambda_\beta$ should have a certain minimum value is not itself sufficient to ensure stability for all Ω. The condition can be made sufficient by a proper and unique choice of the individual values of λ_f and λ_β and these values are found in terms of Λ_1, Λ_2 and Λ_3. All other cases of stability require a larger value of the product $\lambda_f\lambda_\beta$.

An alternative criterion for stability is developed which gives the minimum value of λ_f capable of ensuring stability for all Ω. This, and the preceding criterion, are mathematically exact, and follow from Coleman's equations of motion as applied to the case of a helicopter on isotropic supports.

A brief account is also given of the case of a rotor having inter-blade friction damping as against the viscous damping previously assumed. From author's summary

Astronautics

(See also Revs. 3419, 3437, 3451, 3679, 3761, 3767, 3808, 3814, 3840)

Book—3857. Baker, R. M. L., and Makemson, Maud, An introduction to astrodynamics, New York, Academic Press, Inc., 1960, xiv + 358 pp. $7.50.

The publication of this introductory textbook is a *first* on the American scene. Its importance is that no comparable comprehensive textbook exists in this new, rapidly growing and critical field of the space sciences.

Authors define astrodynamics as "the engineering application of celestial mechanics and allied fields, such as high-altitude aerodynamics, geophysics, ... to the contemporary problems of space vehicles." The word is a combination of astronautics and dynamics, and encompasses trajectory calculation, orbit determination, navigation, guidance, tracking, etc. of space vehicles in their environment, primarily in the gravitational fields encountered.

The first major section of the book deals with fundamentals (minor planets, comets, geometry, coordinate systems, constants) and the second with detailed analysis (orbit determination, n-body problem, perturbation theories, nongravitational forces, observation theory). Such a large field is covered, so much information is presented to the reader, and so many working details are given that the book might be considered an engineering handbook in addition to being a textbook. The treatment of perturbation theory, of nongravitational forces, of observation theory and orbit determination for instance, cannot be found in any other single text at the present time. Several new subjects not previously published in book form appear, such as orbit determination from range and range-rate data, navigation philosophy, glossary of terms, current astrodynamics nomenclature, etc., which make the book useful for the practicing engineer.

The book contains more than 170 up-to-date references, some in the state of publication and several in the form of company reports.

The book was written for the non-astronomer undergraduate student and for the practicing engineer. The authors by necessity made sacrifices to serve the above audience and serve them quickly, since the need for such a book was evident for a number of years. Speedy publication of a book for people who lack basic knowledge in the field and have widely varied interests resulted in a few compromises, such as the lack of error-free presentation of equations, the omission of the elegance of the Hamiltonian approach, the lack of detailed explanation of the reasons behind certain steps, etc. These faults, which will undoubtedly be corrected in the several future expected prints, are insignificant in the light of the book's advantages.

Professors Baker's and Makemson's book is based partially on the lectures of the leader of the Astrodynamics School, Dr. S. Herrick of the University of California, whose ideas, notations, guidance and influence are felt throughout. The Astrodynamics School made a significant, pioneering, useful and timely contribution to assist the workers in the field.

V. G. Szebehely, USA

3858. Brenner, J. L., and Latta, G. E., The theory of satellite orbits, based on a new co-ordinate system, *Proc. Roy. Soc. Lond.* (*A*) **258,** 1295, 470–485, Nov. 1960.

Authors extend analysis of King-Hele [*Proc. Roy. Soc. Lond.* (*A*) **247,** 49–72, Sept. 1958]. By permitting the maximum latitudes of sub-satellite point to vary, a deficiency in King-Hele's result is resolved. Besides usual results, variation of maximum latitude is given and it is shown that the rate of regression of the nodes varies by as much as 20% (for $e = 0.2$). Analysis is valid for all eccentricities. S. H. Maslen, USA

3859. Cook, G. E., and Plimmer, R. N. A., The effect of atmospheric rotation on the orbital plane of a near-earth satellite, *Proc. Roy. Soc. Lond.* (*A*) **258,** 1295, 516–528, Nov. 1960.

Theoretical formulas are derived for the rotation of the orbital plane about the earth's axis and the change in orbital inclination of a near-earth satellite of small eccentricity (< 0.2) due to the atmosphere. It is assumed that the atmosphere is spherically symmetric and has a density varying exponentially with altitude. Comparison of the theory with observation shows reasonably good agreement, although a slightly steeper theoretical curve seems needed. From authors' summary by S. H. Maslen, USA

3860. Kelley, H. J., Gradient theory of optimal flight paths, *ARS J.* **30,** 10, 947–954, Oct. 1960.

An analytical development of flight performance optimization according to the method of gradients or "method of steepest descent" is presented. Construction of a minimizing sequence of flight paths by a stepwise process of descent along the local gradient direction is described as a computational scheme. Numerical application of the technique is illustrated in a simple example of orbital transfer via solar sail propulsion. Successive approxima-

tions to minimum time planar flight paths from Earth's orbit to the orbit of Mars are presented for cases corresponding to free and fixed boundary conditions on terminal velocity components.

From author's summary by D. C. Leigh, USA

3861. Spradlin, L. W., The long-time satellite rendezvous trajectory, *Aero/Space Engng.* **19,** 6, 32–37, June 1960.

The last lap when sending a commuter to a satellite on a given orbit is studied in this essay.

It is supposed that the satellite rotates in a circular orbit having as reference frame, one with its origin in the satellite; with its y axis in earth-satellite direction; its x axis in the orbit plane and z perpendicular to x and y.

The relative movement equations of the commuter are integrated, assuming that the earth attraction force is the only one acting.

The results of this integration, based on the initial position and relative velocity of the commuter and on the variables T (total time required for orbital transfer) and $V_C = (AV)_1 + (AV)_2$ (characteristic velocity), are shown in several graphs; $(AV)_1$ represents the increment of velocity for the initial movement of the operation and $(AV)_2$ the increment so that both commuter and satellite should have the same velocity after a time T.

F. R. Marsicano, Argentina

3862. Friedlander, A. L., and Harry, D. P., III, An exploratory statistical analysis of a planet approach-phase guidance scheme using angular measurements with significant error, NASA TN D-471, 65 pp., Sept. 1960.

Authors explore problem for a two-dimensional maneuver by a vehicle equipped with angle measurement instrumentation. Range is determined from the planet's apparent disk, and angular position is found by planet-star observation. Control action is performed impulsively at three successive position fixes with the aim of minimum velocity expenditure. Standard Monte-Carlo techniques are employed which consist of repeated calculation of random trajectory runs using the measurement error as the random variable. Representative results show an optimum-type guidance of four corrections for a hypothetical scheme, based on computer evaluations.

M. Sanuki, Japan

3863. Broglio, L., Similar solutions in re-entry lifting trajectories, AFOSR TN 60-678 (Universita di Roma, Scu. Ingegneria Aero. SIAR no. 54), 36 pp., Dec. 1959.

Equations for re-entry trajectories were derived, using the distance from the earth's center and the angle below the local horizontal as independent variables. The two simultaneous differential equations were rearranged to give a form suitable for eliminating the ballistic parameter, W/C_DA. While the rearrangement was mathematically sound, reviewer believes that the interpretation of the manipulation is not correct. Using the quantities at peak deceleration as references the equations are made nondimensional. The final equations are independent of the ballistic parameter and are valid for all altitudes. Approximate closed form solutions are obtained by assuming gravitational and centrifugal forces to be equal. For the calculated results both exact and approximate solutions are presented for comparison. The equations indicate that the peak heat-transfer rate, q, and peak heat transfer, Q, vary as square root of the ballistic parameter. Calculated trajectories for a fixed velocity, constant L/D, and specified peak deceleration show that increasing L/D increases the re-entry angle and decreases both q and Q.

The formulation of the problem does permit elimination of W/C_DA as a parameter. However the initial conditions for the problem are stated in terms of the velocity and re-entry angle at the moment of peak deceleration. Usually the re-entry problem is specified by the velocity and a point on the trajectory at commencement of re-entry.

A. Fuhs, USA

3864. Garber, T. B., On the rotational motion of a body re-entering the atmosphere, *J. Aero/Space Sci.* **26,** 7, 443–449, July 1959.

Several aspects of the dynamics of a re-entry body are developed. On the basis of inertial axes fixed in a nonrotating earth, translational and rotational equations of motion are derived from the formulation of expressions for aerodynamic forces and moments. Emphasis is placed on the rotational relationships, resulting in linear differential equations describing the angular position of the body's velocity vector with respect to the longitudinal axis as a function of spin rate, inertia, altitude, and other parameters.

A method of solution is presented from which the stability of the system can be studied. Comparisons are made with previous solutions by other authors. Results indicate that the assumption of negligible gravitational forces of past solutions produced an apparent instability of high drag bodies at low altitudes. The inclusion of g forces at low altitudes and reduced speed is essential to adequately describe the motion.

D. W. Rhoads, USA

3865. Rosamond, D. L., Satellite recovery techniques for optimization of touchdown accuracy, *J. Aerospace Sci.* **28,** 3, 237–243, Mar. 1961.

The variables affecting touchdown accuracy of retrorocket-recovered satellites of nonlifting configuration are interrelated in ways such that various natural optimum combinations exist. For a given nominal orbit there are positions for retrorocket application such that touchdown location is insensitive to burnout velocity. There are also special points for minimizing effects of errors in burnout flight-path angle and burnout altitude. These optimizing points do not vary rapidly with departures of the orbit from nominal.

The natural application of the foregoing is that selecting the proper point to apply retrorocket (velocity change) can significantly improve touchdown accuracy. For best over-all accuracy the chosen point should be based on weighting of the special points according to the relative accuracy to which each burnout variable can be controlled. Touchdown accuracy is also improved by choosing the particular retrorocket direction at which variations in the direction have no first-order effect.

Typical data on these effects, obtained by numerical solution of the equations of motion, are presented and discussed. A brief discussion of the equations of motion is given in an appendix.

From author's summary

3866. Coleman, J. J., Optimum stage-weight distribution of multistage rockets, *ARS J.* **31,** 2, 259–261 (Tech. Notes), Feb. 1961.

In this analysis a generalized method is developed for determining the optimum stage-weight distribution for multistage rockets. Inclusion of the variations in structural factors with stage weights in the optimization process is shown to lead to a more generalized set of optimum conditions. Expression of all rocket weight parameters in terms of the stage weights allows for convenient optimization as well as for a comparison with previous optimization methods. This approach permits improved optimum design over existing methods for maximizing payload ratios for given theoretical velocities, and for maximizing theoretical velocities for given payload ratios. As presented, the generalized method is equally applicable to satellite and space vehicle launchers as well as for ballistic missiles. An evaluation of previous methods is included for comparison purposes, and the limitations of these previous methods are discussed.

From author's summary

3867. Foulders, C. R., Optimum thrust programming of electrically powered rocket vehicles in a gravitational field, *ARS J.* **30,** 10, 954–960, Oct. 1960.

The general problem of optimum thrust programming of an electrically powered rocket under the condition of constant jet power is considered. The thrust vector is assumed to be parallel to the instantaneous velocity vector at all times.... The calculus of variations is employed to obtain analytical expressions for the thrust acceleration program for various problems with a constant gradient of the tangential component of gravitational force....

From author's summary by D. C. Leigh, USA

3868. Etkin, B., Longitudinal dynamics of a lifting vehicle in a circular orbit, AFOSR TN 60-191 (Univ. Toronto, Inst. Aerophys. Rep. 65), 35 pp., Feb. 1960.

Paper concerns the flight of a lifting vehicle in a circular orbit. Proceeding from the characteristics of the basic motion on a given path author uses the method of small disturbances for determining the variation (1) of the velocity components, (2) of the distance from the vehicle to the earth center, (3) of the angular velocity about the c.g., and (4) of the angle of position on the path. For this purpose the motion equations as well as the relations between velocities, rotations and position vector are written. The linearization of these relations leads to the formation of a matrix which solves the problem.

Applications are made in four cases, i.e., (1) constant thrust, (2) thrust proportional to the air density, (3) the density gradient with respect to the altitude is neglected, and (4) zero rotation about the c.g. for the basic motion.

Results of calculations emphasize the importance of the relationship between thrust and altitude and of the density gradient, particularly for altitudes below 300,000 ft. The period of oscillations and their damping appear to vary greatly with the altitude both for stable and unstable motions. Exception seems to be made only by oscillations at high altitudes (above 300,000 ft), whose period tends toward that of a revolution. The motion consists of two series of oscillations superposed over an aperiodic one which has an unstable character for rocket engines and a stable one for breathing engines. The vehicle describes thus a spiral curve and its axis remains almost tangent to the path. Also given are an approximate solution of the problem and a brief examination of the case of an orbit which differs slightly from a circle. This orbit may be represented by a circle eccentrically displaced with respect to the center of attraction.

Paper gives in a simple form interesting results which may be readily used for numerical applications. A series of approximations are included, such as neglecting the variation of aerodynamic coefficients with velocity, the assumption of the proportionality between thrust and air density, neglecting the Coriolis acceleration, use of the ARDC standard atmosphere at altitudes higher than 300,000 ft, and so on. Some of these are mentioned in the paper or are inherent to the method which is based on the linearization of equations. Reviewer believes that although the results are quantitatively disputable, they may be used for the qualitative description of the behavior of a vehicle proceeding from a known basic orbit.

N. S. Tipei, Roumania

3869. Wolowicz, C. H., Drake, H. M., and Vidoan, E. N., Simulator investigation of controls and display required for terminal phase of coplanar orbital rendezvous, NASA TN D-511, 30 pp., Oct. 1960.

Authors describe an analog simulator study of several types of position and velocity displays and of control requirements for a manned astro-vehicle employed in the interception of artificial satellites during the terminal phase of an orbital rendezvous of the satellite. The study is considered in terms of a manned interceptor having a home base at a manned space station which is in a circular orbit around the earth. Interceptions studied are restricted to coplanar conditions and ranges of one-half mile.

At the time of this study scant published literature was available on the interception of an artificial satellite by a manned vehicle. The results of this study indicate that use of translation controls above, parallel and normal to the axis of intercepting vehicle, is effective with additional attitude control enhancing the effectiveness.

Direct visual observation interceptions can be performed effectively up to approximately 50 feet per second. Higher speeds of interception require the aid of range, and rate of closure measuring devices.

B. Zarwyn, USA

3870. A discussion on space research (under the leadership of H. S. W. Massey), *Proc. Roy. Soc. Lond.* (*A*) **253,** 1275, 450–541, Dec. 1959.

Discussion consists of 13 papers (which are reviewed separately) plus introductory remarks by H. S. W. Massey.

1. "Some problems concerning the terrestrial atmosphere above about the 100-km levels" by D. R. Bates. Recent rocket and satellite studies relating to the structure of the thermosphere are analyzed and an analytic model of the thermosphere is presented. 2. "Interplanetary space and the earth's outermost atmosphere" by S. Chapman. The solar corona static temperature distribution is investigated analytically based on the assumptions of thermal conductive and of turbulent adiabatic equilibria and is found to be between the two values thus obtained. Conditions in the coronal gas surrounding the earth are also discussed. 3. "Experiments on cosmic radiation by means of artificial satellites" by C. F. Powell. Author presents a review of up-to-date knowledge of cosmic radiation. He proposes the use of long-lived satellites in high orbits to study the nature and energy levels of cosmic radiations. 4. "Space research in relation to the moon and the nearer planets" by T. Gold. An outline of a study of solar system MHD is given and the type of information-gathering possible with the use of landings on the Moon, Mars and Venus is discussed.

5. "Astronomical observation with the aid of artificial satellites" by F. Hoyle. The advantages of atmosphere free stellar observations are discussed. 6. "Radio astronomical measurements from earth satellites" by A. C. B. Lovell. Paper analyzes some radio astronomy problems that can be advantageously solved by equipment in earth satellites or on the Moon. 7. "Performance, control and guidance of satellite vehicles" by A. W. Lines. The design and performance of an integrated system for over-all satellite operation is discussed. 8. "Radio communication with a lunar probe" by W. T. Blackband. The radio noise problem is analyzed and measures for increasing signal-to-noise ratios are discussed.

9. "Some techniques of physical measurement" by R. L. F. Boyd. The use of Langmuir probes for space measurements is discussed. 10. "Self-contained measuring equipment for electron density and ionic mass spectrum" by J. Sayers. The plasma dielectric method for measuring electron densities and an automatic mass spectrometer method for the analysis of ionic masses in the upper atmosphere are presented. 11. "Geomagnetically-trapped corpuscular radiation" by J. A. Van Allen. Only a bibliography for this paper appears. The paper was published in *J. Geophys. Res.* **64,** 271–286, 1959.

12. "Analysis of the orbits of the Russian satellites" by D. G. King-Hele. Results of analyses of the orbits Sputniks 2 and 3 relating to irregularities in air density in the upper atmosphere, changes in orbital inclination and the earth's gravitational field are discussed. 13. "The United States programme in space research" by H. E. Newell, Jr. Paper presents an outline of planned NASA research as of November 1958.

H. H. Hilton, USA

State of the art—1960 (Surveys by ARS committees), *Astronautics* **5**, 11, Nov. 1960) (Revs. 3871–3883)

3871. Baker, R. M. L., Jr., Astrodynamics, pp. 30, 58, 60.

3872. Farrior, J. S., Guidance and navigation, pp. 34, 150, 152–154.

3873. Linnell, R. D., Hypersonics, pp. 36, 116, 118, 120.

3874. Witherspoon, J. E., Instrumentation and control, pp. 37, 154, 156, 158.

3875. Goldsmith, M., Liquid rockets, pp. 38, 169–170.

3876. Cambel, A. B., Magnetohydrodynamics, pp. 39, 124, 126, 128.

3877. Hunter, M. W., Missiles and space vehicles, pp. 40, 64.

3878. Wang, C. J., Nuclear propulsion, pp. 41, 168–169.

3879. Zarem, A. M., Power systems, pp. 43, 102, 104–106.

3880. Nichols, P. L., Jr., Propellants and combustion, pp. 44, 60.

3881. Brewer, G. D., Solid rockets, pp. 45, 164, 166, 168.

3882. Gerard, G., Structures and materials, pp. 47, 158, 160, 162, 164.

3883. Wislicenus, G. F., Underwater propulsion, pp. 49, 138.

End of Surveys

Ballistics, Explosions

(See also Revs. 3527, 3819, 3869, 3922)

3884. Oshima, K., Blast waves produced by exploding wire, Aero. Res. Inst., Tokyo University, Rep. 358, 194 pp., July 1960.

The formation, propagation and internal structure of the cylindrical blast system from a wire exploded in a shock chamber at reduced pressure is observed by interferometer and schlieren photography. The initial strong blast wave is compared with similarity solutions (G. I. Taylor's intense explosion modified to cylindrical case, and extended in series to lower shock strengths, and to variable energy); the moderately strong blast wave is compared with a "quasi-similarity" solution produced by author, and computed for a range of Mach numbers; the weak blast wave is compared with Whitham's theory. Observations of propagations and decay of blast wave would be more informative if plotted logarithmically. Energy discussion should have been most illuminating, but is, in reviewer's opinion, sketchy and vague.

C. K. Thornhill, England

3885. Bollinger, L. E., and Edse, R., Thermodynamic calculations of hydrogen-oxygen detonation parameters for various initial pressures, *ARS J.* **31**, 2, 251–256, Feb. 1961.

Composition, temperature, pressure and density behind a stable detonation wave and its propagation rate have been calculated for seven hydrogen-oxygen mixtures at 1, 5, 25 and 100 atm initial pressure, and at an initial temperature of 40 C. For stoichiometric mixtures the calculations also include an initial temperature of 200 C. According to these calculations the detonation velocities of hydrogen-oxygen mixtures increase with increasing initial pressure, but decrease slightly when the initial temperature is raised from 40 to 200 C. The calculated detonation velocities agree satisfactorily with values determined experimentally. These values will be published in the near future.

From authors' summary

3886. Patch, R. W., Prediction of composition limits for detonation of hydrogen-oxygen-diluent mixtures, *ARS J.* **31**, 1, 46–51, Jan. 1961.

Two different methods of predicting Chapman-Jouguet detonation limits in hydrogen-oxygen-diluent mixtures are presented for a model of the detonation wave comprising a shock wave followed by an ignition delay region and a combustion region. In the first method, a constant ignition-temperature criterion for the gas behind the shock wave is employed to correlate experimental data; in the second method explosion limits determined from chain branching considerations are employed. Various degrees of rotational and vibrational relaxation behind the shock in the ignition delay region are assumed for both methods to obtain three sets of temperature and pressure conditions behind the shock wave. Both methods are employed to predict detonation limits for various mixtures for which experimentally determined values are available in the literature. It is shown that the constant temperature criterion computed for a gas having complete rotational relaxation but no vibrational relaxation provides the best statistical correlation with experimental values obtained from the literature.

From author's summary

3887. Rasbash, D. J., and Rogowski, Z. W., Gaseous explosions in vented ducts, *Combustion and Flame* **4**, 4, 301–312, Dec. 1960.

Pentane and propane-air mixtures have been exploded in nine straight steel ducts with openings at one end. The ducts were either of 1-ft square section or of 3-in. or 6-in. diameter circular section and varied in length from 6 to 30 ft. The size of the opening varied within the range $K = 1$ to 64 where K is the ratio of cross-sectional area of the duct to the area of the opening. Pressure was recorded and with the longer ducts the progress of the flame was also recorded using ionization gaps. For eight of the ducts with ignition remote from the opening and $32 > K > 2$ the maximum pressure recorded ($P_m Lb/in^2$) was approximately independent of the duct and was given by $P_m = aK$ where a was a coefficient which varied between 0.85 and 1.5. The flame speed also reached a maximum value after the flame had traveled 6 to 12 diameters. With the narrowest tube tested measuring 12 ft long × 3 in. diameter, higher pressures and flame speeds were obtained than with the other vented ducts, although this tube gave a lower pressure with the unvented duct. With all ducts, flame speeds and pressures were very much smaller when ignition was near the vent. A relation is given for the rate of combustion in the ducts as a function of the Reynolds number in the unburnt gas and the pressures developed are discussed on the basis of the combustion rate in the ducts.

From authors' summary

3888. Viktorov, V. V., and Stepanov, R. D., Explosion experiments on models with concentrated charges in uniform ground (in Russian), *Inzhener. Sbornik Akad. Nauk SSSR* **28**, 87–96, 1960.

There are several empirical formulas giving the weight of an explosive charge as a function of its properties and of the size of the crater caused by an underground explosion. Authors quote two such formulas used in the Soviet Union (the Boreskov formula and the Pokrovskii-Fedorov formula) and analyze their relative merits and demerits. They do not seem to be aware of the empirical formulas used in the West like, for example, the Lampson formula given in "The effects of atomic weapons," U.S. Printing Office, 1950, p. 421. The authors made a series of experiments in order to introduce a better formula. The experiments were made on the following model: a cylindrical vessel of diameter 80 cm, height 45 cm,

filled with sand. If the model is scaled down geometrically, say N times, then the dynamic similarity requires that the gravitational acceleration be N times greater. This requirement has been met by placing the model on a specially designed accelerometer. The experiments carried out with varying charges and at different depths yielded data which the authors express in dimensionless form: energy of the charge versus its size and the volume of the crater. The results are tabulated, plotted, and compared with large-scale experiments. The agreement seems to be very satisfactory.

In the above-mentioned reference, page 420, we find the following statement: "it has been shown that the model law is obeyed and the predictions on size based on empirical data are reasonably reliable," which indicate that model experiments have been carried out in the USA as well. T. Leser, USA

3889. Zvolinskii, N. V., On the emission (radiation) of an elastic wave from a spherical explosion in the ground, *Appl. Math. Mech.* (*Prikl. Mat. Mekh.*) **24,** 1, 166–176, 1960. (Pergamon Press, 122 E. 55th St., New York 22, N. Y.)

The mean stress and the equation of motion are calculated under conditions of spherical symmetry. These equations are supplemented by Hooke's law. The propagation process of the shock wave is then studied in terms of four consecutive stages. For each stage the radial stress and the velocity are calculated. Instances of transition of one phase of motion into the other, the radius and volume of the compacted zone, the radius of the cavity, the energy of the radiated elastic wave and the energy irreversibly lost in plastic deformation can then be determined qualitatively. G. E. Jarlan, Canada

Acoustics

(See also Revs. 3524, 3528, 3783, 3855, 3922)

3890. Lysanov, Yu. P., The problem of surface resonance on a sinusoidal surface, *Soviet Phys.–Acoustics* **6,** 1, 71–74, July/Sept. 1960. (Translation of *Akust. Zh., USSR* **6,** 1, 77–80, Jan./Mar. 1960 by Amer. Inst. Phys., New York, N.Y.)

A plane acoustic wave at normal incidence is scattered by a rigid sinusoidal reflecting surface of small amplitude. Rayleigh's infinite series approximation to the total field near the surface is adapted to yield amplitudes of the grazing spectra. It is shown that the first-order spectrum (referred to the spatial period of the sinusoidal surface) can have an amplitude much larger than that of the incident wave. This phenomenon is termed surface resonance; it falls off rapidly for higher spectral orders, essentially disappearing after the second. W. W. Soroka, USA

3891. Tartakovskii, B. D., Sound field in the focal plane of spherically converging beams, *Soviet Phys.–Acoustics* **6,** 1, 92–96, July/Sept. 1960. (Translation of *Akust. Zh., USSR* **6,** 1, 96–100, Jan/Mar. 1960 by Amer. Inst. Phys., New York, N.Y.)

The amplitude distribution of the acoustic particle velocity and of acoustic pressure in the focal plane of a beam of spherical sound wave is treated theoretically when the flare angle is finite and the amplitude distribution over a wave front is nonuniform. When this last amplitude distribution is expressed as a polynomial it is possible to express the solution in terms of certain special functions. The theory is illustrated by computations. F. Ursell, England

3892. Jackson, F. J., and Nyborg, W. L., Sonically-induced microstreaming near a plane boundary: Part 1, The sonic generator and associated acoustic field; Part 2, Acoustic streaming field, *J. Acoust. Soc. Amer.* **32,** 10, 1243–1250, Oct. 1960; **32,** 11, 1387–1395, Nov. 1960.

An experimental arrangement is described which permits controllable generation of small-scale acoustic streaming, i.e., "microstreaming" near a plane boundary S. This arrangement, which consists essentially of a cylindrical bar oscillating longitudinally above the boundary S in question, has been used in studies of sonically-produced effects at a fluid-solid interface. The present paper deals with first-order pressure and velocity fields in the thin layer of fluid between S and the vibrating face of the bar. Theoretical expressions are developed, based on a simple model in which incompressible flow is assumed. Experimental determination of the pressure field was accomplished by means of a special hydrophone arrangement which measures the pressure at points along the plane boundary. The first-order theory agrees well with experiment, and is thus judged satisfactory as basis for a detailed treatment of the microstreaming flow, to be given in a subsequent paper. A byproduct of the work is a method for calibration of small hydrophones.

In a previous article, Jackson described an experimental arrangement suitable for generating small-scale near-boundary acoustic streaming, i.e., "microstreaming," in a precise and controllable manner. Such microstreaming is of particular interest insofar as it can have considerable influence on processes taking place at a solid-liquid interface. In the present paper, results of a comprehensive study of the microstreaming flow field associated with the aforementioned experimental system are discussed in some detail. Photographs are shown of the various flow configurations, and data are presented on streaming speeds as a function of significant experimental parameters. Theoretical expressions are developed along lines of conventional acoustic streaming theory to describe various features of the flow. The correlation between theory and experimental results is found to be good when certain criteria are fulfilled. From authors' summary

3893. Blackman, A. W., Effect of nonlinear losses on the design of absorbers for combustion instabilities, *ARS J.* **30,** 11, 1022–1028, Nov. 1960.

Absorption characteristics of perforated-liner test configurations with open areas between 0.5 and 10 per cent were measured for frequencies between 200 and 1200 cps at sound pressure levels between 100 and 160 db, using an impedance-tube technique. Evaluation is based on analysis by U. Ingard, *J. Acoust. Soc. Amer.* **25,** p. 1037, 1953. Amplitude-dependent contribution to acoustic resistance was found to be significant above 100 db, and is given in form of graphs and empirical relations. Also presented is a correction term for effective length of apertures. An approximate design procedure for screech absorption liners based on these data is proposed. G. H. Markstein, USA

3894. Nettleton, R. E., Compressional relaxation in liquids, *J. Acoust. Soc. Amer.* **31,** 5, 557–567, May 1959.

A general approach to the study of sound absorption in liquids is proposed in terms of a multiplicity of irreversible thermodynamic processes. Gibbs equation of entropy balance is used to determine the nonequilibrium thermodynamic functions. The theory is then applied to carbon tetrachloride and to chloroform, but simplified to one structural relaxation time based on a shear viscosity theory of Mooney and one thermal relaxation time in each. The calculated sound absorption coefficients are smaller than published experimental values. This is ascribed, quite reasonably, to the use of only two relaxation times instead of several. The structural relaxation mechanisms seem to have been particularly underestimated, and for this a continuous distribution of relaxation times is suggested. W. W. Soroka, USA

3895. Dobbs, E. R., and Finegold, L., Measurement of the velocity of sound in liquid argon and liquid nitrogen at high pressures, *J. Acoust. Soc. Amer.* **32,** 10, 1215–1220, Oct. 1960.

An ultrasonic interferometer, consisting of a barium titanate ceramic cylinder suspended in a high-pressure vessel, has been used to measure the velocity of sound in liquid argon and liquid nitrogen at temperatures near their boiling points and at pressures up to 135 atm. The apparatus is suitable for measurements at much higher pressures, since it is rugged, compact, and has no moving parts. An analysis of the resonances obtained over a frequency range $0.2/_0$ to $1.7/_0$ (where $/_0$ is the thickness resonant frequency of the ceramic cylinder) has shown that a simple relation exists between the velocity in the liquid and the zeros of the Bessel functions J_0 and J_1 for frequencies near $0.5/_0$ and $1.5/_0$. The velocity data obtained agree with previous measurements on liquid argon and liquid nitrogen at atmospheric pressure, but show that the velocity of sound in these liquids is not a linear function of pressure, as had been supposed by Itterbeek. Using known density data, the adiabatic compressibility and ratio of the specific heats γ have been found for liquid argon and liquid nitrogen at 90 °K. For argon, γ falls slightly from 1.97 to 1.89 as the pressure rises to 135 atm, but for nitrogen γ rises from 1.50 to 1.79 with the applied pressure, suggesting the hindering of intramolecular motions at the higher pressures. From authors' summary

3896. Saenmark, K., Acoustic forces and torques on a system of strips, *Appl. Scient. Res.* (*B*) **8,** 1, 13–28, 1959.

In continuation of an earlier paper, author reports some calculations of the forces and torques on a system of strips. Numerical calculations are presented for the case of two coplanar strips with the parameter-value $kb = 1$ and an arbitrary angle of incidence. Further, simple and yet rather accurate expressions for the forces and torques are derived. These relate the forces and torques of the present problem to those acting on a single strip, present alone in an unlimited radiation field.

From author's summary

3897. Mayer, W. G., Determination of ultrasonic velocities by measurement of angles of total reflection, *J. Acoust. Soc. Amer.* **32,** 10, 1213–1215, Oct. 1960.

A simple method, based on the total reflection of a sound beam from a liquid-solid boundary at the critical angles, is described. With this method it is possible to measure the velocity of longitudinal and shear waves in the *solid* by locating the angles of maximum reflection in the *liquid*.

From author's summary

Micromeritics

(See also Revs. 3657, 3793)

3898. Wilcox, J. D., and June, R. K., Apparatus for study of the breakup of liquid drops by high velocity airstreams, *J. Franklin Inst.* **271,** 3, 169–183, Mar. 1961.

Article surveys previous investigations of high-velocity breakup of liquids, by Engel, Hansen and Domich, and Lane, and the breakup of drops and sprays by Priem. In present research, data in air flow in the range of Mach 1.0 were sought. Steady-flow air nozzle was considered unsuitable because an initially spherical drop cannot be formed within the jet. A suddenly applied air flow was needed and, to obtain this, two techniques were tried, (1) by blast gun and (2) by shock tube. The blast gun is a pressurized cylindrical chamber, separated from an open-ended expansion chamber by a frangible diaphragm. At high pressures, the bursting diaphragm allows a shock wave and an air blast to form within the expansion chamber and to form an air jet directed onto the externally located test object, in this case a liquid drop which was supported, without any cross hairs or filament, on an air-suspension column. Experiments showed this method unsatisfactory, owing to spurious action of jet vortex and unevenness of air flow.

The shock tube also has a frangible diaphragm between the pressurized chamber and the expansion chamber, but the end of the expansion chamber is closed, and the test area is enclosed within the shock tube. The flow in the shock tube was found to be uniform and adjustable, and the pressure behind the shock front could be closely regulated. The shock tube was set up vertically, and the drop was allowed to fall freely within the tube, and meet the shock wave. Shadowgraph pictures were obtained of the successive stages of disintegration of the drop, using a closely timed electric spark.

The experimental arrangements for both devices, the flash circuit and triggering circuit, and the operational procedure are described; photographs of the disintegrating drops provide evidence to support previous findings that the high-speed airstream strips off droplets from the surface of the large drop, deforms the drop in an interaction of the accelerating, inertia and surface tension forces, after which a chaotic disintegration of the bulk of the drop takes place. Present paper is primarily a description of the apparatus, and its capabilities and limitations. It is a clear exposition of the requirements, and means of attack, of research on high-speed liquid atomization, with its increasing importance for numerous fields of application. K. J. DeJuhasz, USA

3899. Dodd, K. N., On the disintegration of water drops in an air stream, *J. Fluid Mech.* **9,** 2, 175–182, Oct. 1960.

A theory is developed based on the very limited experimental evidence to predict the distortion and disintegration of a water drop when it is exposed to a stream of air with continuously increasing relative velocity. The theory is applied to water drops situated in the path of a solid sphere moving through the air.

From author's summary by G. H. Lean, England

3900. Kurabayasi, T., Atomization of liquid by means of a rotating nozzle (on the disintegration modes and droplet sizes), *Bull. JSME* **3,** 11, 352–357, Aug. 1960.

Flow from rotating nozzles, and the behavior of the issuing jets, was studied by means of high-speed photography. A shallow cylindrical container, fed with liquid at its center, was rotated at high speed, producing thereby a strong centrifugal force on the liquid. The liquid issued through nozzles drilled into the cylindrical wall. Containers of 10 to 20-cm diam, nozzles of 0.4 to 1.2-mm diam, and flow rates of 0.1 to 6 cm^3/sec were employed. Five typical modes of disintegration could be distinguished: (1) dripping, (2) smooth jet, (3) wavy jet, (4) partially sprayed jet, and (5) spray. Paper shows graphs of the Sauter mean diameter as a function of velocity, and presents mathematical expression for the region of wavy jet, and for the spray. The maximum diameter is found to be approximately twice the mean diameter.

K. J. DeJuhasz, USA

3901. Kurabayasi, T., On the thicknesses of smooth jets discharged from a fixed and a rotating nozzle, *Bull. JSME* **3,** 11, 358–363, Aug. 1960.

Droplet size produced from a continuous liquid jet depends mainly on its thickness. Author discusses the contraction of smooth liquid jets, issuing from a fixed and from a rotating nozzle, due to acceleration and surface tension, and presents formulas for it. The physical factors influencing the liquid jet are expressed by the Weber number; when this exceeds the value 4, the physical properties have no further influence on the thickness of the jet. For the length of the continuous portion of the jet paper presents the formula of Tanasawa and Toyoda. Relationship between the cases of a fixed nozzle and a rotating nozzle is discussed and good agreement is found between the values computed from the formulas and those obtained experimentally. Author sug-

gests that the results are applicable to the filamentation of viscous liquids by means of a rotating nozzle. This paper, together with the preceding review, confirms some earlier research results, and contains some novel findings; they can be regarded as useful additions to previous spray literature.

K. J. DeJuhasz, USA

3902. Poblarzhin, P. I., An investigation of the influence of internal vorticity on atomising quality and the jet of atomised fuel (in Russian), Dvigateli Vnutr. Sgoraniya (MVTU, **76**), Moscow, Mashgiz, 1958, 84–103; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3718.

An experimental investigation of the influence of vorticity in the fuel stream of an open-type burner nozzle on the quality of atomization and the enclosed angle of the atomized fuel jet, the vortices being created by consecutive chokes arranged before the exit opening. The tests were made with a model of an open burner nozzle, in which differing degrees of vorticity of the full stream could be created by throttling the fuel in nozzles with a single, centrally-arranged aperture of varying size, the distance between the nozzles being adjusted by setting a movable plate between them. In the experiments the rate of fuel flow and pressures in front of the entry and exit nozzles, mean diameter of the fuel droplet apex angle of the fuel jet and the flow coefficients of the entry and exit nozzles were determined. The experiments were made under continuous fuel feed. The fuel was injected into air at atmospheric pressure. Droplet sizes were measured by catching them on a smoked plate, set in a special drop-catcher. The prints of the droplets on the smoked plate were measured under the microscope with 280 diameters magnification. The tests were made with diesel fuel of a specific gravity of 0.853. The apex angle of the fuel jet was determined photographically. From hydraulic analysis of variant burner forms the author derives relationships between the pressures in front of the entry and exit nozzles, and the rate of flow of the fuel, also between the flow coefficients of these nozzles and the pressure gradient in the nozzle, as well as the pressure in front of the nozzle. The measurements of droplet size showed that the mean droplet diameter is smaller for the burner with two nozzles than with only one. Consequently, the presence of a second throttling nozzle or choke in the burner materially influences the droplet dimensions. The apex angle of the fuel cone for the burner with two nozzles is considerably greater than for that with only one nozzle, although in the first case the pressure in front of the exit nozzle is lower. The specific fuel comsumption of the tested burner variants has been calculated, and the specific energy balances set up. It is found that the open-type burner with two throttling sections gives finer atomization and a wider cone angle of the fuel jet than an open-type burner with only one nozzle. These differences can be explained by swirling of the fuel stream in the space between the nozzles.

Yu. F. Dityakin

Courtesy Referativnyi Zhurnal, USSR

3903. McLaughlin, R. T., Jr., The settling properties of suspensions, *Proc. Amer. Soc. Civ. Engrs.* **85,** HY 12 (*J. Hydr. Div.*), 9–41, Dec. 1959.

Mathematical equations representing gross behavior of particles in suspension are derived and discussed. Particular notice is taken of hindered settling and flocculation. Finite-difference equations are established with required initial and boundary conditions being extensively discussed. Difficulties of applying numerical analysis to engineering problems not only involve spatial characteristics of diffusion but also resuspension, initial concentration, hindered settling or flocculation, and their effect upon diffusion. Model laws for flocculating suspensions involve a different length-scale ratio than the Froude law for the flow. Thus for model studies two approaches are used. First, the model is used to study the flow characteristics with the measured flow properties and the sediment characteristics being combined to predict removal or deposition. Second, the settling is studied in a model with an empirical time-scale factor being used for prototype removal prediction.

Experiments with quiescent flocculating suspensions were performed to determine mean settling velocity as a function of depth and time. Periodically, samples were simultaneously withdrawn from various depths. The severalfold increase of mean settling velocity with time during flocculation leads to the conclusion that detailed study of the suspension will be of equal or greater significance than a study of the flow characteristics. Significant conclusions are stated concerning stilling tanks and canal deposition based solely upon the properties of the suspension.

Author was awarded the Alfred E. Noble prize of 1960 by ASCE and ASME for this paper. Reviewer concurs.

M. R. Carstens, USA

3904. Cornwall, J. B., and Davison, R. M., Rapid counter for small particles in suspension, *J. Sci. Instrum.* **37,** 11, 414–417, Nov. 1960.

Equipment based on a photoelectric detection method is described which has been designed for counting apple cells (approximate size distribution 70–500 μ length) but which may be used with any reasonably opaque particles of suitable size which can be held in suspension in a clear low-viscosity liquid. The accuracy of a single run is about ±3% including sampling errors. This error may be reduced by averaging several samples.

From authors' summary

3905. Behn, V. C., Derivation of flow equations for sewage sludges, *Proc. Amer. Soc. Civ. Engrs.* **86,** SA 6 (*J. San. Engng. Div.*), 59–81, Nov. 1960.

This paper has been prepared to bring together the solution of equations which have been derived by others and reported in various texts, journal articles, and theses. The extent of coverage is limited to time-independent non-Newtonian liquids flowing in capillary and rotational viscometers and smooth pipes.

From author's summary

3906. Pluzhnikov, V. N., The influence of silting on the operation of hydraulic power installations (in Russian), *Elektr. Stantsii* no. 5, 32–35, 1958; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3892.

Investigations have been made at a hydroelectric power plant on the manner in which the composition of the suspended silt influences the amount of wear in the turbine elements. Analysis of the changes in the operating characteristics of hydroelectric power units has shown that the fundamental cause of turbine wear is the enormous quantity (40–50 thousand tons per annum) of silt passing through the turbines, consisting of solid minerals. The greater part of the particles in suspension (over 95%) is of 0.1–0.07-mm size. The parts of the blades most subject to abrasion are the trailing edges and front faces. Crumbling of the blade edges raises the coefficient of cavitation which, in conditions of a high suction head, causes cavitation phenomena on the backs of the blades. Serious damage is also caused by cavitation at surface irregularities produced by abrasion.

E. A. Boldyirev

Courtesy Referativnyi Zhurnal, USSR

Porous Media

(See also Revs. 3534, 3580, 3646, 3731)

3907. Yih, C.-S., Flow of a non-homogeneous fluid in a porous medium, *J. Fluid Mech.* **10,** 1, 133–140, Feb. 1961.

Author considers the steady-state flow of a fluid through a porous material when the fluid viscosity and density are known

functions of position. By a variable transformation, the nonlinear equations governing such a flow are reduced to a linear form. If the density is constant, it is shown that the flow pattern of a fluid with variable viscosity is the same as that which would obtain for a constant viscosity fluid under the same boundary conditions. The actual flow velocity at any point is proportional to the calculated velocity-viscosity ratio. Equations are presented for two-dimensional and axisymmetric flows where both viscosity and specific gravity are variable.

Solutions are presented for the flow between two parallel plates with and without an impermeable barrier to the path of flow. The solution technique introduced in this paper should be of interest to those concerned with the analysis of ground-water motion or of petroleum reservoir behavior. G. C. Wallick, USA

3908. Wooding, R. A., Rayleigh instability of a thermal boundary layer in flow through a porous medium, *J. Fluid Mech.* **9,** 2, 183–192, Oct. 1960.

Author investigates the stability to small disturbances of flow in the thermal boundary layer produced when hot fluid rises slowly through a semi-infinite permeable medium towards a horizontal cooled surface. Flow is shown to be stable below a calculated critical value of an appropriately defined Rayleigh number.
B. R. Morton, New Zealand

3909. Hammad, H. Y., Seepage losses from parallel canal systems, *Proc. Amer. Soc. Civ. Engrs.* **86,** EM 4 (*J. Engng. Mech. Div.*), 43–50, Aug. 1960.

Author studies the steady two-dimensional seepage flow from a system of parallel, identical, and equally spaced canals running in a semipervious layer of finite thickness supported by a highly permeable layer. The piezometric head in the lower permeable layer is constant and slightly lower than the canal water level. Substituting the free water surface in the semipervious layer with a horizontal line coinciding with the canal water level, two steps of conformal mapping are used and a simple seepage discharge formula is obtained. G. Noseda, Italy

3910. Kovacs, Gy., Computation of seepage flow under dams (in Hungarian), *Viz. Közl.* no. 2, 293–330, 1960.

Author discusses the theoretical foundations of the methods for computation of the discharge and compares five methods: Pavlovsky transformation, electrical analogy, permeable layer of infinite thickness, empirical relationships, and an original method using approximations of hydraulic nature. He computes the discharge with the five methods for contour lines most used in practice and gives the results as functions of geometrical parameters. As the value of the coefficient of permeability has an inherent inaccuracy he considers a deviation of 10–15% as admissible and suggests a new semi-empirical formula which furnishes discharge values with sufficient accuracy for any arbitrary combination of plane foundation slab with one row of sheet piles.
A. Kezdi, Hungary

3911. Gyalokay, M., Halek, V., and Zajicek, V., Solution of geohydrological problems of riparian areas with special regard to the upper section of the central Danube (in Hungarian), *Viz. Közl.* no. 4, 496–518, 1959.

Authors introduce—after a sketchy treatment of the theory of seepage—for the approximate investigation of ground water movement in three dimensions the method of the fictitious diaphragm: taking a horizontal plane, which is an approximate flow line with known gradients, they assume the seepage beneath this plane as one-dimensional, in the way that the discharge and the distribution of the gradient are the same as in the original case. The computation furnishes a fictitious depth. Putting this into the linearized form of the Boussinesq equation, the latter may be solved in a simple way.

Authors point out the limited value of theories and present results of model tests carried out with the Hele-Shaw gap method, investigating the water movement in sand masses lying between two river beds with fluctuations in the water levels. The results confirmed the theoretical computations except for the case when the differences between the water levels are great. It could be stated that there exists a vertical component of velocity.

In the last part, the article emphasizes the usefulness of hydrological methods for the investigation of ground water movement in territories of great extent. A. Kezdi, Hungary

3912. Gerber, C.-S., On the existence of percolation by free filtration through a pervious medium with vertical walls (in French), *C. R. Acad. Sci. Paris* **250,** 23, 3776–3778, June 1960.

3913. McNamee, J., and Gibson, R. E., Displacement functions and linear transforms applied to diffusion through porous elastic media, *Quart. J. Mech. Appl. Math.* **13,** 1, 98–111, Feb. 1960.

A typical problem with which paper is concerned is determination of displacements, stresses and pore water pressure in a clay porous medium through which water diffuses under the action of stresses applied at the surface. The basic partial differential equations of Biot are used, and two displacement functions $E(x, z, t)$ and $S(x, z, t)$ determining the stresses and displacements are introduced. E and S are then assumed in the form of Fourier transform integrals of two new functions E_c and S_c, and the partial differential equations for E_c and S_c are subsequently converted into ordinary differential equations by means of a Laplace transform. Problems of plane strain and of axially symmetric strain are treated in general, although there are no particular numerical examples worked out. Generalization to a three-dimensional treatment is briefly shown.

The steady-state ($t \longrightarrow \infty$) solution (in which excess pore pressure = 0) of the diffusion equations here is identical with the solution of the corresponding (linear) elastic equations for plane and radially symmetric strain, and the limiting forms of E and S are shown to be related to stress functions of the theory of elasticity.

The displacement functions here are especially useful in problems for a semi-infinite body or infinite layer when the stresses or displacements are prescribed on the surface. The success of the method depends mainly on the possibility of evaluating certain integrals in the complex plane. M. Morduchow, USA

3914. Salwa, K., and Walden, H., The filtration of liquid in a horizontal slot (in Polish), *Rozprawy Inz.* **8,** 3, 413–420, 1960.

The solution of the filtration problem in a homogeneous horizontal oil-bearing bed with a horizontal slot is obtained. The axially symmetric problem is considered for simplicity, the influence of the aperture, the pressure loss in the slot and the width of the slot being neglected. It is assumed that the pressure at the surface of the slot is a function of r, that is $g = g(r)$. Author obtained the function $g(r)$ experimentally. With these assumptions the accurate solution is obtained by means of Hankel's integral transformation. Theoretical results are compared with experimental ones obtained with a model filled with sifted, homogeneous sand. The empty slot is separated from the sand by means of copper gauze. Under the action of pressure water flows through the sand and the slot and is captured in a graduate thus enabling the measurement of the flow rate. A set of piezometers was used for the measurement of radial pressure distribution. The measurement results of pressures and flow rates are collated in a table and are used for the determination of the function $g(r)$.

A similar problem is treated by Piskunov in his work "Filtration of a liquid in a bedding with a horizontal slot" where the in-

fluence of the aperture on the flow rate and the thickness of the slot filled with a body of much higher permeability than the oil-bearing medium is studied. This problem was solved by a method different from that of K. Salwa and H. Walden.

In view of the theoretical and experimental results the paper is intended for both scientific workers and engineers, since an appraisal of the influence of a horizontal slot on the flow rate in an oil-bearing bed is made possible. F. Labisch, Poland

3915. Oroveanu, T., Some considerations on flow of incompressible fluids through inhomogeneous porous media (in German), *Rev. Mécan. Appl.* 3, 4, 463–479, 1958.

Geophysics, Hydrology, Oceanography, Meteorology

(See also Revs. 3491, 3528, 3529, 3736, 3857, 3911)

Book—3916. Translations in earthquake engineering. (Translations of papers published in the Russian language), Berkeley, Calif., Earthquake Engineering Research Institute, 1960, ix + 150 pp. $3.25. ($5. clothbound)

The translations are restricted to seven Russian papers on earthquake engineering and the Russian standards and regulations for buildings in seismic regions.

The first paper deals with the fundamental premises on the dynamic theory of seismic resistance. The analysis of seismograms and accelerograms established a basis for the assumption that the composite seismic disturbance is made up of a comparatively small number of wave trains, with each of these trains confined to a narrow frequency range.

The second paper develops a method of designing buildings for seismic forces. Seismic design ratings for various types of structures are set up.

The third paper investigates the design of flexible structures for seismic loads. The procedure for the calculation requires the plotting of envelope diagrams for bending moments, for shearing forces, etc., followed by a verification of the adequacy of the various structural elements.

The fourth paper proposes a simplified method for earthquake-resistant design of structures. The method is based on the determination of the natural period of vibration and the corresponding shape functions.

The fifth paper is a study on the interaction between masonry filler walls and enclosing frame when loaded in the plane of the wall. The data confirm the validity of the concept that the interaction of frame and filler wall following the formation of boundary cracks is equivalent to a frame system with a compression diagonal replacing the filler wall.

The sixth paper discusses certain design problems of reinforced-concrete frame structures for seismic regions. General patterns of the possible behavior of frame structures during earthquakes are analyzed and recommendations for the distribution of rigidities of their structural components are recommended.

The seventh paper shows vibration characteristics of three tall buildings (up to 40 stories). The influence of nonstructural elements upon their vibration and stiffnesses are evaluated and formulas for the approximate determination of natural frequencies are derived.

The standards and regulations for building in seismic regions are of particular interest. They are subdivided into nine sections: (1) Earthquake zone of an area or a building site and design ratings of buildings and structures; (2) Planning cities and towns; (3) Seismic forces for residential, civic, industrial and farm buildings and structures; (4) Industrial and civic buildings and structures; (5) Water works and sewerage; (6) Highways and railways; (7) Hydraulic structures; (8) Rural structures, and (9) Field work and control of seismic requirements.

The reviewer would like to compliment the translators for a difficult job well done. R. K. Bernhard, USA

3917. Gurevich, G. I., The length and form of a wave produced as the result of a rupture (in Russian), *Izv. Akad. Nauk SSSR, Ser. Geofiz* no. 3, 261–264, 1955; *Ref. Zh. Mekh.* no. 5, 1959, Rev. 5466.

It is generally assumed when investigating the simplest single-dimensional problem on the propagation of the impulse of initial deformation, assigned in a portion of an ideally elastic medium, that the load creating the initial deformation is shed instantaneously. A model of this type serves as an illustration of the generally accepted presentation of the genesis in the earth's crust of a tectonic earthquake. The further assumption is advanced that when the elastic deformation attains a certain critical value, determinable by the strength of the rock formation, in the corresponding portion of the earth's crust (the earthquake's epicenter) the rupture takes place suddenly, that is the walls suddenly find themselves with no connection between each other. This is followed by accelerated displacements resulting in equilibrium (slip) which releases energy for elastic deformation which, in turn, is converted into energy for seismic waves. Actually, the rupture is not instantaneous but is really a process of disruption developing with time with ever-increasing velocity; the cohesive forces between the walls of disintegration do not reach zero value suddenly but decrease with time. Practically speaking, the "instantaneous" act for the final formation of the division plane is really the last stage of a previous and a slower process. If this circumstance is taken into account when solving the problem in question, i.e. the propagation of the impulse in an elastic medium, the author is justified in his introduction of the concept of not a sudden but of a gradual ever-accelerating fall of the load in the region of initial deformation. Here it is found that the conditions governing the form and the period for the wave coming from its source to any point in the medium are different from those customarily proposed for the sudden shedding of the load. Development in displacements over large periods precedes the impulse in the usual problem, which in the investigated simplest model may serve as an analog for the assumed "slow motions" preceding the earthquake.

Courtesy Referativnyi Zhurnal, USSR

3918. Michielsen, H. F., Fifth harmonic of Earth's gravitational field, *ARS J.* **30,** 10, 976–978 (Tech. Notes), Oct. 1960.

Book—3919. Remenieras, G., Engineering hydrology [L'hydrologie de l'Ingénieur], Paris, Eyrolles, 1960, 413 pp. 40. NF.

Textbook on continental hydrology for use of hydraulic engineers presents in lucid form the contemporary state of this subject in France. First part covers a study of factors producing runoff: precipitation, topographical and geological characteristics of basins, influence of temperature, evaporation, transpiration. The second part analyzes river flow: hydrometric stations, determination of river discharge, reductions of runoff, study of flood waves, unit diagram method, forecast of maximum discharge. In addition to general discussion several problems are elaborated in detail.

Book is well edited and illustrated. French terminology of hydrology is established more logically; hydrogramme (hydrogram, better than hydrograph), hydrogramme unitaire (unit hydrogram, better than unitgraph). Bibliography is given at the end of every chapter. French hydrology is of great interest for our hydrologists as a means of comparison and development of methods in use.

S. Kolupaila, USA

3920. Goddet, J., The initial stages of the transport of materials under wave action (in French), *Houille Blanche* **15,** 2, 122–135, Mar./Apr. 1960.

Experiments were made at the National Hydraulics Laboratory of France to determine incipient transport conditions for bed materials. An experimental law was established relating density and diameter of particles and amplitude, period and depth of waves. Existence of laminar boundary layer was assumed. This assumption was confirmed when experiments showed that mechanism of particle entrainment is identical to that for a steady flow. Paper reports experiments to determine incipient motion, assumptions made, velocity distribution in the boundary layer, and application of these results to development of similitude criteria for models with erodable bed. A. Balloffet, USA

3921. Goddet, J., and Jaffry, P., Similitude laws for sediment transport under the simultaneous action of waves and currents (in French), *Houille Blanche* **15,** 2, 136–147, Mar./Apr. 1960.

Authors review bed load movement formulas for steady flow, as developed by Meyer-Peter, Esguiasaroff and Shields. Then a summary is presented of formulas developed at the National Hydraulics Laboratory of France, for bed load motion under waves. Authors then present compatibility conditions for models representing both types of motions simultaneously, first for relatively large grains and secondly for relatively fine grains with respect to the boundary-layer thickness. Authors conclude that similarity conditions for gravel transport under waves and steady flow are compatible only for a non-distorted model. In the case of sand, a non-distorted model would involve the use of extremely fine materials in the model. Distortion is needed in order to use sand of practicable size. Geometric distortion combined with distortion of wave amplitude inversely proportional to fourth root of geometric distortion appears to be the best solution. A. Balloffet, USA

3922. Hunt, J. N., Palmer, R., and Penney, W., Atmospheric waves caused by large explosions, *Phil. Trans. Roy. Soc. Lond.* (*A*) **252,** 1011, 275–315, Feb. 1960.

The basis of this paper is the theory of free oscillations in the atmosphere developed by Pekeris [*Phys. Rev.* (*2*) **73,** p. 145, 1948] and Scorer [*Proc. Roy. Soc. Lond. A* pp. 201, 137 (1950)]. They supposed that the lapse rate was constant in the troposphere and the temperature constant in the atmosphere. Here after confirming the general conclusions of these papers the problem is generalized to include (1) the possibility of upward traveling dispersive waves and (2) an atmosphere in which the temperature was constant in each of two layers separated by a discontinuity. The idea behind (1) is to be able to discuss the propagation of upward traveling pulses such as might be generated by a ground explosion. The model in (2) is thought to give a better approximation to the temperature in the real atmosphere.

These results are used to discuss the atmospheric oscillations associated with a ground source with particular reference to the Siberian meteor of 1908. K. Stewartson, England

3923. Filatov, A. N., The spiral motions of a barotropic fluid (in Russian), *Trudi In-ta Matem. i Mekhan. Akad. Nauk UzSSR* no. 21, 97–106, 1957; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3772.

The author analyzes the spiral motions of an ideal, barotropic fluid. The first chapter examines uniform motions; i.e., those for which, in the equation rot $V = \lambda V$, $\lambda = \text{const}$ (V = velocity vector). It is demonstrated that the possibility of the uniform, spiral motion of a barotropic fluid depends on fulfilment of the condition V grad $\frac{1}{2} v^2 = 0$. A general solution is further given for unidimensional motion in the cases of identity of the Lamy coefficients, $H_1 = H_3$. In the two-dimensional case it is demonstrated that the solution of the problem can be reduced to two differential equations, one of which is nonlinear. The necessary conditions are stated for which, as a result of the addition of two uniform spiral motions in the presence of barotrophy, the resulting complex motion will likewise be spiral. The second chapter deals with non-uniform, spiral motions. It is in this case assumed that the scalar factor $\lambda(x, y, z)$ in the equation rot $V = \lambda V$ satisfies the condition $\lambda = k\rho$ ($k = \text{const}$, ρ = density). A general solution is derived for the case that all determining parameters are functions of a single coordinate. In the two-dimensional case, a system of two differential equations is set up, which must be satisfied by two functions σ and ρ expressing all the other characteristics of the motion. Yu. P. Ladikov

Courtesy Referativnyi Zhurnal, USSR

3924. Moller, F., Radiative equilibrium in the neighborhood of the ground (in German), *Meteorol. Rdsch.* **13,** 5, 134–139, Sept./Oct. 1960.

The temperature distribution which would result in the lowest 300 m of atmosphere in the case of radiative equilibrium was calculated. Water vapor was considered to be the only absorbing constituent. With terrestrial (nocturnal) radiation, super-adiabatic temperature gradients, increasing toward the surface, resulted. Absorption of solar radiation by the water vapor leads to a decrease of the temperature gradient. These results contradict the observed lapse rates, and author concludes that radiational effects do not control the temperature structure near the ground. Turbulent mixing processes are so much faster that the lapse rate is in fact almost entirely due to the rate of turbulent transfer. Some estimates of these rates of transfer are also given.

It seems thus that the lapse rate in the surface layer is largely independent of radiation, while the surface temperature is dependent on it.

From author's summary by W. Hitschfeld, Canada

3925. Businger, J. A., and Kuhn, P. M., On the observation of total and net atmospheric radiation, *J. Meteorol.* **17,** 4, 400–405, Aug. 1960.

Paper describes results from one balloon flight to a height of about 24 km, carrying a blackened silver sphere, a Suomi and Kuhn two-stream radiometer, a single horizontal disk radiometer and a Gergen black-ball total radiation radiometer, and measuring air temperature as well. The different radiation equilibrium temperatures obtained make excellent sense on the basis of general theory and the peculiarities of the instruments. Disk measurements (or for that matter black-ball total radiation instruments) do not quite seem to permit computation of downward flux if upward flux is known. On the other hand, suggestion is made that difference between temperatures of suitable total-radiation instrument and air might relate in practically useful way to flux divergence, i.e. radiational heating rate. A simple blackball is not suitable for this, however, as the desired characteristics of such an instrument include blackness through most of the terrestrial spectrum, but high reflectivity in the 8 to 12 micron "window". Such characteristics are not only hard to achieve; reviewer believes that they will not produce the desired results in atmospheric layers where ozone is important. W. Hitschfeld, Canada

3926. Herman, B. M., and Abraham, F. F., A note on the two-stream theory of radiational transfer through clouds, *J. Meteorol.* **17,** 4, 471–473, Aug. 1960.

3927. Phillips, N., Blumen, W., and Cote, O., Numerical weather prediction in the Soviet Union, *Bull. Amer. Meteorol. Soc.* **41,** 11, 599–617, Nov. 1960.

This article reviews the research done in the Soviet Union through 1959 on the theory and practice of numerical weather prediction by hydrodynamical methods. Russian meteorologists have used the same geostrophic forecast system as have other meteor-

ologists and have carried out a number of test forecasts with electronic computers. Comparatively little has been published so far in objective weather-map analysis, general-circulation experiments and the use of non-geostrophic equations.

From authors' summary

3928. Dukhin, S. S., and Deryagin, B. V., Methods of calculating the precipitation of disperse particles in a flow on an obstacle (in Russian), *Kolloidn. Zh.* **20**, 3, 326–328, 1958; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 4019.

An investigation of the precipitation of inertialess particles from the flow of an aerosol on an obstruction in the presence of an external field of force. The theorem is proved that the concentration of the particles is retained along the trajectory in the case of a solenoidal field. A calculation is made, for the precipitation of inertialess particles suspended in water, on an ascending bubble, by the action of gravity forces. E. A. Novikov

Courtesy Referativnyi Zhurnal, USSR

3929. York, W. C., Shu, H. H., and Rouleau, W. T., Remarks on the numerical integration of the equations of droplet growth, *J. Meteorol.* **17**, 4, 456–459, Aug. 1960.

3930. Mason, B. J., The evolution of droplet spectra in stratus cloud, *J. Meteorol.* **17**, 4, 459–462, Aug. 1960.

Naval Architecture and Marine Engineering

(See also Revs. 3653, 3883)

3931. Vokler, H., Ship model balance for measuring longitudinal, transverse and flooding stability (in German), *Schiffstechnik* **7**, 36, 62–66, Apr. 1960.

The Institute for Naval Architecture at the Technical University in Vienna (Austria) has developed a novel and simple method for preparing ship models and for measuring all characteristics of the floating ship form. The models are made of plasticine and pierced longitudinally by a strong "spit" serving as a spine. The heavier-than-water models hang on counterweights so that any desired displacement and trim can easily be adjusted. Inclining moments can be imposed by mere shifting of weights. Results are obtained quicker and in part with better accuracy than by calculation. In addition, any part of the model's volume can be easily made open to the surrounding water and the desired permeability of the flooded room can be established. For the first time additional immersion, trim and stability levers in any case of leakage can be measured simultaneously. Thus it is possible to investigate and to improve the degree of unsinkability even for freighters and coasters for which, so far, the respective calculations have been considered as being too circumstantial.

Author claims that the accuracy of measurement is quite satisfactory; even the usual hydrostatic curves for the upright position can be ascertained by the new, simple method. The Research Institute for Naval Architecture in Vienna is prepared to carry out measurements with this new type of equipment.

From author's summary by A. Lenkey, USA

3932. Martin, M., McLeod, C., and Landweber, L., Effect of roughness on ship model rolling (in English), *Schiffstechnik* **7**, 36, 67–70, Apr. 1960.

In rolling tests of small, bare-hull ship models at zero speed of advance, turbulence stimulation along the bilges is necessary. Authors used plastic pins of 1/8-in. diam and 1/16-in. height, cemented to the hull by shellac. They found that at a low speed of advance the model develops a stable, laminar boundary layer in which the pins are immersed. This is probably the reason for the ineffectiveness of the pins at speeds less than 1 knot. At greater Reynolds numbers the laminar boundary layer is less stable and the pins again become effective.

If the boundary layer along the hull is principally turbulent, due either to a sufficiently high Reynolds number or to turbulence stimulation near the bow, the pins along the bilges should no longer be needed as stimulators. Furthermore, because a boundary layer becomes thinner with increasing speed, the parasite roll damping of the pins would be expected to increase with speed, as it was observed. From authors' summary by A. Lenkey, USA

3933. Firsov, G. A., The application of the hypothesis of A. N. Krylov to the theory of rolling (in Russian), *Sudostroenie* no. 11, 12–16, 1957; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3801.

An analogy is drawn between the Froude-Krylov hypothesis in the theory of the rolling of ships, and the action of a homogeneous, accelerated flow on a body. The Froude-Krylov hypothesis is reduced to an assumption of the permeability of the ship's hull with reference to the incident seaway. For the case of a homogeneous, accelerated, advancing flow, such a hypothesis leads to the action of the inertia force of the displaced volume of liquid. On this basis, expressions are set up for the forces acting on a permeable ship's hull, from the direction of the incident waves in the form of three-dimensional integrals. For the forces determined by Krylov's theory, this form is equivalent to the transformation of the surface of the wave pressures into three- dimensional integrals according to the Ostrogradsky-Gauss theory, using the pressure integral, or the Euler equations, for an incident wave flow.

M. D. Khaskind

Courtesy Referativnyi Zhurnal, USSR

3934. Blagoveshchenskii, S. N., The calculation of the principal part of the disturbing moment in the rolling of a ship in regular waves (in Russian), *Trudī Nauchno-Tekhn. O-va Sudostroit. Promsti* **7**, 2, 133–148, 1957; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3802.

An investigation of the purely rolling motion of a ship's hull symmetrical about the center of gravity, in regular waves on an oblique course. In accordance with the Froude-Krylov hypothesis and the linear theory, an approximate determination is made of the disturbing moment, founded on the neglect of small quantities of higher order than $(B/\lambda)^3$, where B is the beam of the hull, and λ the length of the incident waves. For the final calculations, the hull lines are given in analytical form, and the results of the calculation reduced to correction coefficients, for which equations and curves are given. It is observed that in a number of cases the amplitude of the disturbing moment on an oblique course is appreciably greater than for a ship broadside on the waves.

M. D. Khashind

Courtesy Referativnyi Zhurnal, USSR

3935. Mandel, P., The potential of semi-submerged ships in rough water operation, Soc. Nav. Arch. Mar. Engrs., Ann. Meet., 24 pp., Mar. 1960.

Author discusses the response of ships to excitation while sailing through rough water. He broadly outlines the zones of serious heaving and pitching for head, overtaking and following seas, and points out that the zones of subcritical, critical and supercritical (in regard to resonant response) must be outlined not only for head seas but also for overtaking and following seas and, moreover, that these boundaries depend also on the magnitude of the excitation in terms of the ratio of the component wavelength to the ship length. A chart of these regions in terms of the natural frequency parameter (for either pitch or heave) as a function of Froude number is presented to show the regions covered by all conventional ships of

400 feet in length in seas corresponding to a 35-knot fully developed storm.

The program of research which generated this paper has been concerned with forms whose natural frequencies are considerably less than those of conventional ships and, in particular with semisubmerged ships, i.e., forms consisting of bodies of revolution with a thin central strut-like form (in side elevation). The large reduction in waterplane provides for a low natural period. The remainder of the paper deals chiefly with the results of towing-tank experiments with such a form. The smooth-water resistance of the semisubmerged form was found to be quite high when compared with a series 60 hull of block coefficient 0.60. In regard to motions, it is considered that

(a) semisubmerged forms will experience large motions only in overtaking and following seas rather than in head seas,
(b) this form suffers far less speed reduction in the critical zone which more than compensates for its higher calm-water resistance.
(c) unusually large pitch and heave amplitudes were observed at $F = 0.10$ which corresponds to a condition well removed from resonance.
(d) no significant peak of damping in pitch was observed at $2\pi F\sqrt{4g/T} = 1/4$, F being the Froude number, T the pitching period, L the ship length and g the acceleration of gravity.

It is the reviewer's opinion that the advantages of a semisubmerged form having large lateral area in the surface-piercing component cannot be appreciated without tests in oblique waves which will certainly point up the requirements for lateral stability and control. Some of the surprising results observed in the data should be compared with theory devised to fit this form rather than that developed for conventional ships. J. P. Breslin, USA

Friction, Lubrication and Wear

(See also Revs. 3579, 3755, 3790, 3906)

3936. Kragel'skii, I. V., Wear criteria for materials, *Soviet Phys.-Doklady* **4,** 6, 1359–1363, May/June 1960. (Translation of *Doklady Akad. Nauk SSSR (N. S.)* **129,** 5, 1016–1019, Nov./Dec. 1959 by Amer. Inst. Phys. Inc., New York, N.Y.)

Author and N. B. Demkin have shown that in a sliding process the ratio of the area of real contact A_r and the apparant area A_a as function of the relative approach of the two rubbing surfaces a/b_m (a = absolute approach distance, b_m maximum height of the roughness) is given by $A_r/A_a = b \cdot (a/b_m)^\gamma$ with the constants b and γ which depend on the roughness of the surfaces. Based on this relation the volume v_1 of the plastically deformed material can be calculated. It results $V_1 = A_r \cdot a/(\gamma + 1)$. This deformed material is partly worn away. It is assumed that wear takes place if the plastic deformation is repeated n times on an average. The value of n is fixed by the mechanism of breaking of frictional bonds. With this assumption $V_d = V_1/n$ is obtained for the quantity of material abraded on the path d matching the diameter of the contact area. The energy consumed on the path d for the deformation of the volume V_1 is given by $W_d = V_1 \cdot c \cdot \sigma_s$ (σ_s = yield point, c coefficient depending on the geometry of the matrix and the work-hardening capacity of the material). Therefore for the energy criterion, i.e. the quotient of the abraded volume to the friction work, $I_W = 1/n \cdot c \cdot \sigma_s$ is obtained. In engineering practice the linear wear parameter $I_h = h/L = V/A_a \cdot L = V_d/A_a \cdot d = [a/(\gamma + 1) \cdot n \cdot d] \cdot (A_r/A_a)$ (h height of the abraded layer, L length of the friction path, V abraded volume) is usually employed. Because the linear wear parameter depends on the ratio A_r/A_a and with this on the load and the nominal dimensions of the surface, it is inconvenient for use as a characteristic of the wearing qualities of the material. Therefore author proposes to use the so-called specific wear $i_h = V_d/A_r \cdot d = a/(\gamma + 1) \cdot n \cdot d$ for this purpose. For i_h depends only on the shape of the surface roughness and the mechanism of breaking of frictional bonds and not on the material. This is shown by the author by means of experimental data of Khrushchov and Babichev. U. Rost, Germany

3937. Sata, T., Abe, K., and Nakajima, K., Study on wear in shearing process by means of irradiated tools, *Scient. Pap. Inst. Phys. Chem. Res., Tokyo* **54,** 3, 307–312, Sept. 1960.

Tool wear in shearing process of sheet metals is studied with punches and dies of high-speed steel irradiated in an atomic pile. Circular discs of 10-mm diameter are punched from sheet metals of 0.5-mm thickness of low-carbon steel, stainless steel and silicic steel in dry and lubricated states. Wear of punch and die is determined by measuring the radio activity of punched sheet and disc. Effects of material of sheet metal, tool clearance, and lubrication on tool wear are examined.

From authors' summary

3938. Germer, L. H., The erosion of relay contacts, *Wear* **3,** 3, 188–199, May/June 1960.

The wear of relay contacts is chiefly electrical and due to discharges occurring when the contacts are opened and closed. Arcs cause more damage than do glow discharges and account for most of the damage. Short arcs at relay contacts are of two types which predominantly erode, respectively, the anode and the cathode. The type of arc which occurs and its duration are enormously influenced by foreign material on the contact surfaces. The chief source of foreign material in many applications is organic vapor from the atmosphere, which can be decomposed to form surface carbon. Thus the atmosphere in which relays operate is often of great importance in determining their performance. These various factors influencing the wear of relay contacts have been isolated and are now quite well understood.

From author's summary

3939. Khruschov, M. M., A new method for the determination of wear of machine parts, *Wear* **3,** 1, 60–71, Jan. 1960.

Method determines absolute value of local linear wear. Principle is change in size of converging groove made previously in rubbing surface and calculation of linear wear value at this place. Special apparatus was developed for cutting groove with diamond bit and measuring groove with microscope. Results cited include cylinder bore wear of automotive engine and fuel pump plunger wear.

Method appears novel and useful if employed carefully. Reviewer believes surface waviness would distort wear picture if insufficient readings were taken. Worthwhile extension of work would be correlation of local wear values and total wear rates as measured by radioactive techniques.

W. A. Pullman, England

3940. Sanin, P. I., Shapoleva, E. S., Ulyanova, A. V., and Kleimenov, B. V., The effect of synthetic additives in lubricating oil on wear under friction, *Wear* **3,** 3, 200–218, May/June 1960.

A number of substances with different structure have been synthesized and their influence on frictional wear studied. High molecular fatty esters, organo-chloro and organo-sulphur compounds, phosphites, thiophosphites and thiophosphates, and chloroalkyphosphonates have been investigated.

The action of chlorine, sulphur, and phosphorus atoms on the anti-wear property of various compounds has been determined. In substances being studied one can observe a direct influence of chlorine, sulphur, and phosphorus on the anti-wear properties of the compounds, namely, on the critical load value and wear at loads above the critical one.

Among the anti-wear additives, organo-thiophosphorus and organo-chlorophosphorus compounds have been shown to be of greatest interest.

Some chemical aspects of the mechanism of anti-wear additives have been considered. From authors' summary

3941. Tipei, N., and Constantinescu, V. N., Influence of the law of variation of the mixing length on the turbulent motion in the lubricant layer (in English), *Rev. Mécan. Appl.* **5**, 6, 729–738, 1960.

Authors consider Reynolds equations simplified for the flow through the lubricant film. The inertial terms are neglected while the viscosity and turbulent stress terms and the pressure gradient are retained. The viscosity and turbulent stress terms vary normal to the flow direction. For expressing the turbulent stress, Prandtl's mixing length is used. Three forms of mixing length variation, i.e., linear, sinusoidal and parabolic variations, symmetrical with respect to the semidistance between the two walls, are considered. After performing the calculations for these three forms of variation, it is concluded that the resulting differences for the velocity distribution are negligible, while the differences for the pressure variation and friction force are of a particular importance. The criterion of selecting the form of variation which is closest to reality is a comparison with Laufer's experiments which show that for the velocity distribution the linear variation yields slightly better results than the parabolic one.

St. N. Savulescu, Roumania

3942. Lemmon, D. C., and Booser, E. R., Bearing oil-ring performance, *ASME Trans.* **82** D (*J. Basic Engng.*), 2, 327–334, June 1960.

Characteristics of oil-rings for bearings, such as ring speed, oil delivery, transition speed above which the centrifugal force hinders the increase of oil delivery, were investigated experimentally with rings ranging from 2¾ to 16½-in. diameter and at journal speeds up to 4000 fpm. The results of experiments were summarized in empirical formulas taking the oil characteristics, the geometry of the ring and journal, the operating conditions, etc., as parameters. It is reported that the oil delivery could be increased severalfold with the use of suitable guides and scrapers with rings. Y. Hori, Japan

3943. Livesey, J. L., Inertia effects in viscous flows, *Inter. J. Mech. Sci.* **1**, 1, 84–88, Jan. 1960.

In problems dealing with hydrodynamic lubrications, the inertia term in the equation of motion usually is neglected in comparing the pressure and the viscous terms. The present paper presents a method for estimating the inertia effect.

The method described amounts to solving the equation of motion approximately in its integral form by first assuming an appropriate velocity distribution. A demonstration is given by referring to a particular example of a radial flow between two parallel plates of infinite extent. For the special case treated, the inertia effect is shown to be large enough to change the sign of the radial pressure gradient even at values of Reynolds numbers usually considered as low. C. T. Chang, Denmark

3944. Sugimoto, Y., A theory of lubrication in journal bearings with an elastically bent shaft, *Wear* **2**, 5, 329–334, Aug. 1959.

In long bearings the bending of the shaft may influence significantly the pressure distribution within the lubricant; in particular there may be two distinct maxima of the pressure. This effect can be predicted if Reynolds equation is solved with the appropriate specification of the clearance. Here an approximate variational method is applied [which was used in a different instance by C. Weber, AMR **4**(1951), Rev. 1862 and D. F. Hays, AMR **12**(1959), Rev. 2751] and results obtained in a special case are given. Note: the criterion used to define the region of cavitation is not clear to the reviewer.

This paper is the translation of a paper published in Japanese in *J. Japan Soc. Mech. Engrs.* **15**, 1949.

G. Capriz, England

3945. Zhukovsky, Yu. V., The steadiness of a rigid shaft running in bearings with fluid friction (in Russian), *Trudi Kbar'kovsk. Politekhn. In-ta* **14**, 43–52, 1958; *Ref. Zh. Mekh.* no. 4, 1959, Rev. 3492.

An analysis of the conditions for steady running in the presence of the resisting force of the oil film.

From author's summary
Courtesy Referativnyi Zhurnal, USSR

3946. Hunter, J. J., and Hughes, C. J., Shaft position indicator for use with journal bearings, *Brit. J. Appl. Phys.* **12**, 2, 73–80, Feb. 1961.

A description is given of equipment using transistors and designed for the indication and measurement of the position of the shaft within the bush of a journal-bearing system. Shaft movements cause variations in the impedance of inductive transducers, unbalancing the ac bridge of which they are part. The bridge output, in the form of an amplitude-modulated carrier, is supplied to an ac amplifier and then demodulated to recover a voltage proportional to shaft displacement. By monitoring the bearings on two diameters at right angles and supplying the demodulator outputs to the *X*- and *Y*-plates of a cathode-ray oscilloscope, a polar plot of shaft movement is possible and the form of vibration can be observed directly.

Although designed for use on a bearing of about 1-in. diameter, the equipment is easily adjustable for other bearing sizes and can give useful information with shaft speeds up to 20,000 rev/min.

Circuit details are given and discussed and an assessment is made of the accuracies of the various units.

From authors' summary

3947. Floberg, L., The two-groove journal bearing, considering cavitation, Trans. Chalmers Univ. Technol., Gothenburg, Sweden no. 232 (Inst. Machine Elements no. 13), 32 pp., 1960.

Author deals with the calculation of 360° journal bearings with an oil groove 90° before and another 90° after the load line. The result is obtained by adding a solution for an upper half shell with zero pressure to the solution for centrally loaded 180° bearings previously published by author [AMR **14**(1961), Rev. 575]. In calculation of the power loss it must be taken into account that the upper half is a cavitation region with oil and air strips and linear velocity distributions owing to the lack of pressure gradient. If at higher eccentricities cavitation starts in the lower half of the bearing the oil temporarily loses its grip to the bearing surface in the second groove. This involves a small decrease of power loss. But this is cancelled by an increased power loss originating from the fact that at the bearing sides oil being sucked into the bearing causes the oil strips to be somewhat broader than required by theory.

In the case of a ring-lubricated bearing the determination of the bearing temperature starts from the heat-equilibrium condition $E_{tot} = c \cdot \rho \cdot Q' \cdot (t_a - t_r) = \alpha \cdot A \cdot (t_r - t_s)$ (E_{tot} = total power loss, Q' = side leakage, c = specific heat of the oil, ρ = density of the oil, t_a = average bearing temperature, t_r = oil temperature in the reservoir, t_s = temperature of the surroundings, α = coefficient of thermal transmission by convection, A = area of the bearing housing).

Then author treats the case that both grooves of the bearing are filled with cold oil of atmospheric pressure by an oil pump. Here the total oil flow is composed of the quantity which enters the low half of the bearing already calculated by Raimondi-Boyd and the

quantity which enters the upper half being equal to $U \cdot b_s/2$ (U = surface velocity, b_s = thickness of the gap behind the second groove). The average bearing temperature is calculated with the assumption that the direct heat transition from the bearing housing to the air is negligible compared to the heat led away by the oil. If oil is not changed in the grooves the calculation of the bearing temperature cannot be based on the total oil flow but on the side leakage representing the circulation of the oil.

Paper contains all values which are needed for designing two-groove journal bearings. Moreover two optimum design examples are given. U. Rost, Germany

3948. Ausman, J. S., Torque produced by misalignment of hydrodynamic gas-lubricated journal bearings, *ASME Trans.* **82** D (*J. Basic Engng.*), 2, 335–341, June 1960.

A first-order approximation to the solution of Reynolds equation is obtained by means of a small parameter technique, which the author has already successfully applied to similar problems [AMR **10**(1957), Rev. 1651; Conference on Lubrication and Wear, Instn. Mech. Engrs., 1957, p. 39–45]. Here the equation is specified for compressible lubricant and misaligned bearings; the small parameter is the misalignment angle. It is shown (with greater detail in the discussion) that deduced values of torque are exact to terms of the third order; hence the graphs provided should be of direct interest to designers. Compressibility has a striking effect on the "attitude angle", especially in long bearings; the effect is confirmed experimentally. G. Capriz, England

3949. Floberg, L., The optimum thrust tilting-pad bearing, Trans. Chalmers Univ. Technol., Gothenburg, Sweden no. 231 (Inst. Machine Elements no. 12), 23 pp., 1960.

Design procedure for multiple pad tilting-pad thrust bearing with minimum power loss is outlined. Quantities assumed are load, speed and minimum film thickness. Solution leads to optimum number of pads and pad dimensions. Computer solutions for a single rectangular pad obtained by Jakobbson and Floberg [Jakobbson, B. and Floberg, L., "The rectangular plane pad bearing," Gothenburg, 1958] form the basis for this design procedure.

W. J. Anderson, USA

3950. Pecken, H., Analysis of spherical bearings (in German), *Forsch. Geb. Ing.-Wes.* (*B*) **26**, 4, 117–128, 1960.

The Reynolds equation is solved for the spherical bearing under the assumptions that (1) the pressure gradient in the circumferential direction is negligible in comparison with that in the axial direction, and (2) that the film thickness depends only upon the circumferential coordinate. Curves are supplied to facilitate the use of the solution thus obtained in closed form in bearing design. A numerical example is included.

All quantities used are clearly defined, the paper is well illustrated, and the discussion is adequate.

W. C. Orthwein, USA

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